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Environmental Carcinogens and Human Cancer: Estimation of Exposure to Carcinogens in the Ambient Air

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16. ABSTRACT

In this study, a methodology for ambient exposure analysis of carcinogens was developed based on a pilot study of the Detroit Metropolitan area. The specific aim of the analysis was to identify high and low exposure areas within the study area. Four known or suspected carcinogens and groups of carcinogens: BaP, trichloroethylene, nickel and its compounds, and cadmium and its compounds were studied. The analysis of ambient exposure to BaP consisted of the use of the Air Quality Display Model (AQDM) to simulate levels of BaP which might have existed during 1956 to 1960. The analysis for BaP involved a multistep procedure. In order to examine the accuracy of AQDM predicted BaP ambient concentrations, present conditions (1975-1976) were simulated and compared against known concentrations in the area. Next, BaP emissions for the period 1956-1960 were estimated by analyzing past trends for significant sources. This emissions data base, along with meteorological data for the same period, was used as an input to ADQM to predict historical exposure to BaP. The analysis for the other three carcinogens was less detailed than that for BaP. It was comprised of estimation of emissions and calculation of emission density for each of the three carcinogens. For nickel and cadmium, it also included a comparison of spatial variation in emissions with measured air quality patterns in the Detroit area. The results of this study were very encouraging in light of the scarcity of data on carcinogens. Excellent correlation between observed and estimated concentrations was obtained for BaP. In the case of nickel and cadmium, the estimated emission density patterns matched well with observed air quality patterns. Due to the lack of data on ambient concentrations, a similar comparison was not possible for trichloroethylene. The carcinogen exposure patterns developed in this study are being used in the selection of population samples for an epidemiological study of the area.

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Estimation of Exposure to Carcinogens in the Ambient Air

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ENVIRONMENTAL CARCINOGENS AND HUMAN CANCER

Estimation of Exposure to Carcinogens in the Ambient Air

by

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FOREWORD

The many benefits of our modern, developing, industrial society are accompanied by certain hazards. Careful assessment of the relative risk of existing and new man-made environmental hazards is necessary for the establishment of sound regulatory policy. These regulations serve to enhance the quality of our environment in order to promote the public health and welfare and the productive capacity of our Nation's population.

The Health Effects Research Laboratory, Research Triangle Park, conducts a coordinated environmental health research program in toxicology, epidemiology, and clinical studies using human volunteer subjects. These studies address problems in air pollution, non-ionizing radiation, environmental carcinogenesis and the toxicology of pesticides as well as other chemical pollutants. The Laboratory participates in the development and revision of air quality criteria documents on pollutants for which national ambient air quality standards exist or are proposed, provides the data for registration of new pesticides or proposed suspension of those already in use, conducts research on hazardous and toxic materials, and is primarily responsible for providing the health basis for non-ionizing radiation standards. Direct support to the regulatory function of the Agency is provided in the form of expert testimony and preparation of affidavits as well as expert advice to the Administrator to assure the adequacy of health care and surveillance of persons having suffered imminent and substantial endangerment of their health.

This report is one of a series under the main title Environmental Carcinogens and Human Cancer. A broad range of objectives directed to the quantitative assessment of the relationship between environmental exposure to carcinogens and increased risk of cancer were addressed. Particular attention was given to development of methodologies and appropriate data bases as well as to identification of community populations for study of specific carcinogen-cancer associations. The series of reports documents the methodologies, resource data, and findings resulting from project activities.

F. G. Hueter, Ph. D.
Acting Director,
Health Effects Research Laboratory

ABSTRACT

In this study, a methodology for ambient exposure analysis of carcinogens was developed based on a pilot study of the Detroit Metropolitan area. The specific aim of the analysis was to identify high and low exposure areas within the study area. Four known or suspected carcinogens and groups of carcinogens: BaP, trichloroethylene, nickel and its compounds, and cadmium and its compounds were studied. The analysis of ambient exposure to BaP consisted of the use of the Air Quality Display Model (AQDM) to simulate levels of BaP which might have existed during 1956 to 1960. The analysis for BaP involved a multistep procedure. In order to examine the accuracy of AQDM predicted BaP ambient concentrations, present conditions (1975-1976) were simulated and compared against known concentrations in the area. Next, BaP emissions for the period 1956-1960 were estimated by analyzing past trends for significant sources. This emissions data base, along with meteorological data for the same period, was used as an input to AQDM to predict historical exposure to BaP. The analysis for the other three carcinogens was less detailed than that for BaP. It was comprised of estimation of emissions and calculation of emission density for each of the three carcinogens. For nickel and cadmium, it also included a comparison of spatial variation in emissions with measured air quality patterns in the Detroit area. The results of this study were very encouraging in light of the scarcity of data on carcinogens. Excellent correlation between observed and estimated concentrations was obtained for BaP. In the case of nickel and cadmium, the estimation between observed and estimated concentrations was obtained for BaP. In the case of nickel and cadmium, the estimated emission density patters matched well with observed air quality patterns. Due to the lack of data on ambient concentrations, a similar comparison was not possible for trichloroethylene. The carcinogen exposure patterns developed in this study are being used in the selection of population samples for an epidemiological study of the area.

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SECTION 1

INTRODUCTION

In order to investigate the association between exposure to a carcinogen present in the ambient air and incidence of cancer, high and low carcinogen exposure areas need to be identified. Human carcinogenesis generally has a long latency period--spanning 5 to 40 years. Such a latency period implies that identification of current high and low exposure areas is not sufficient in itself; historical trends in spatial variations must be examined. Estimation of historical exposure to a carcinogen is possible if monitoring data on the carcinogen are available for several sites for a period of years. It is recognized that sufficient information on ambient concentrations to depict historical and spatial variations is not available for any of the 23 carcinogens or group of carcinogens selected for this study (Table 1). The objective of this study was to develop and apply alternative approaches for characterization of carcinogen exposure.

Based on a pilot study of one area, a methodology for first generation ambient air exposure analysis of carcinogens was developed. The specific aim of the exposure analysis was to identify high and low exposure areas within a multicounty study area. This report gives a rationale and technical approach for the methodology used and describes results for the first pilot study area--Detroit metropolitan area.

The summary and conclusions of ambient exposure analysis for the Detroit metropolitan area are presented in the next section. A detailed discussion of the rationale and technical approach for characterization of ambient exposure to carcinogens appears in Section 3. Using this approach, exposures to various carcinogens prevalent in the ambient atmosphere of selected study areas were estimated and analyzed. Section 4 describes available data bases, specific approaches, and results for each carcinogen included for exposure analysis in the Detroit pilot study area.

The results of the carcinogen exposure analysis performed in this task, in the form of spatial gradation or differences in ambient concentrations, are used to support an epidemiologic study. In order to examine the degree of association between high carcinogen exposure and increased cancer risk, samples of cancer victims and matched control groups are selected from both high and low exposure areas. The details of this primary data collection and its analysis will be reported as the epidemiologic study is completed.

TABLE 1. RANKED LIST OF CHEMICALS WITH CARCINOGENIC POTENTIAL*

Priority Group	Number †	Chemical Name
I		
Known or suspected human carcinogens	1	Benzene
	2	Vinyl chloride monomer
	3	Acrylonitrile
	4	Nickel and its compounds (primarily nickel carbonyl and nickel subsulfide)
	5	Ethylene dibromide
	6	Asbestos
	7	Chromium and its compounds (primarily calcium chromate)
	8	Benzo-a-pyrene (BaP)
	9	Arsenic trioxide
	10	Benzidine
II	11	Ethylene oxide
Carcinogenic to laboratory animals	12	Carbon tetrachloride
	13	Trichloroethylene
	14	Chloroform
	15	Vinylidene chloride
	16	Cadmium and its compounds
	17	Dimethyl sulfate
	18	Chloromethyl methyl ether (along with bischloromethyl ether)
III	19	Formaldehyde
Carcinogenicity not confirmed or chemical is no longer produced	20	Tetraethyl lead
	21	Pentachlorophenol (PCP)
	22	Polychlorinated biphenyl (PCB)
	23	Beryllium and its compounds

* Reference 1.

† Ranked within priority group of U.S. production.

SECTION 2

SUMMARY AND CONCLUSIONS

Due to the generally perceived lack of information on the sources of carcinogenic substances, their emissions and their concentrations in the air, ambient exposure analysis would seem impossible at the present time. This is no doubt true for many carcinogens for which there is little or no information on emissions or ambient concentrations. However, for some carcinogens piecemeal information related to emissions and air quality exists. An attempt has been made in this task to show that various pieces of information can be integrated to obtain some understanding of differences in ambient exposures to carcinogens on a subregional basis.

Candidate pollutants for exposure analysis for the Detroit study areas were chosen based on their carcinogenic risk and feasibility of analysis. Benzo-a-pyrene (BaP) offered the most promise; it had one of the most comprehensive sets of emission factors of the 23 carcinogens selected in this study. Similarly, some historical air quality data were available for BaP in the Detroit area. The exposure analysis for BaP consisted of air quality modeling with a routinely used multisource model to simulate present (represented by 1975-76) and past (1956-60) ambient concentrations in the study area. The 1975-76 conditions were simulated to check accuracy of prediction by estimating concentrations at BaP monitoring sites. The agreement between observed and predicted BaP concentrations was excellent; $R^2 = 0.98$. The 1956-60 concentrations were estimated to assess past exposures. Past emissions were estimated by analyzing trends for significant sources. The air quality information for the period 1956-60 was very limited; only 12 monthly observations were available for one site during 1958-59. No statistical analysis was possible, but for the one site for which data were available, the observed and predicted concentrations were close (observed, 15.0 ng/m^3; predicted, 14.1 ng/m^3). Based on the 1956-60 simulation, high and low BaP exposure areas were identified (see Figure 17, page 66).

Three other carcinogens--nickel,* cadmium,* and trichloroethylene--were also analyzed for the Detroit study area. However, in these cases, the data were inadequate for an extensive analysis. Simulation of the atmospheric diffusion process was not included and only 1976 emission density and air quality profiles were examined. For nickel and cadmium, crude air quality patterns developed based on limited data matched well with emissions profiles. Since emissions and air quality patterns are based on two independent data bases, the agreement was impressive. The

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* Certain metal-containing compounds are identified as carcinogens. However, due to a lack of data on specific compounds, the analysis and discussion included in this report refers only to metals in their elemental form.

high/low exposure areas for nickel and cadmium will be shown in Figures 26 and 31, respectively. In the case of trichloroethylene, no air quality data were available and uncertainty exists about its behavior in the atmosphere. Consequently, only limited confidence can be attached to its high/low exposure characterization which is solely based on emissions data (see Figure 21, page 72).

It has been demonstrated in this task that a first generation characterization of ambient exposure is possible for a limited number of carcinogens, primarily, trace metals and combustion products such as BaP. For most organic chemicals very limited information on emissions and virtually no air quality concentration data are available. As information on source emissions and ambient concentrations becomes available, it should be possible to characterize ambient exposures to these chemicals.

SECTION 3

TECHNICAL APPROACH

RATIONALE

The objective of this study was to estimate variations in ambient exposure to carcinogens within an area consisting of a few counties. A detailed exposure analysis requires information on time-varying ambient concentrations at several locations which are spatially representative. For more precise estimates of exposure, factors such as indoor-outdoor concentration differentials, occupational exposure, etc., need to be addressed. However, these were not within the scope of the present study.

The extent of information which describes existing levels of carcinogens varies from data on ambient concentrations at a few sites in an area to no air quality data at all. Even when the ambient air quality data are available, these are seldom sufficient to describe spatial variations. Historical data which can describe past air quality are even more scarce. For most carcinogens there is little information available on past ambient concentrations. Ambient air quality has been monitored for a few carcinogens but generally it has been limited to one or two locations in any given region. Consequently, air quality information alone cannot describe spatial or historic changes in ambient exposure to carcinogens, and there was a need to develop another method for determining high and low exposure areas.

Exposures could be estimated by air quality models which calculate concentrations at designated locations by simulating an atmospheric diffusion process in the area under consideration. Primary input to these models comprises information on emission sources and meteorological conditions. Due to uncertainties in the actual diffusion process and limited emission and meteorological data, results of the model calculations have to be checked or calibrated against measured concentrations for a period which is compatible with the input data. Historical trends in spatial distribution of ambient concentrations could be established if the air quality model predicts present conditions fairly well, and if there is some information on past air quality at one or more locations. For estimating historical emissions, significant emission sources need to be identified and trends in process parameters relating to those sources have to be examined. Similarly, the extent of emission control in the past has to be considered.

The modeling approach may not be justifiable if the input data are insufficient and no air quality information exists. In such cases, a simpler analysis such as plotting of emission density would be preferable. Emission density is determined by computing emissions per unit

area. It does not involve simulation of atmospheric diffusion, yet is useful in distinguishing between high and low exposure areas. Moreover, plots of emission density would be of a significant value if there is some air quality information available to support identification of high and low exposure areas.

OVERALL APPROACH

The approach for identification of high and low exposure areas within a study area consisted of the following steps:

- Examination of availability of data on air quality and emissions
- Selection of an approach for exposure analysis
- Identification of emission sources
- Compilation of appropriate emission factors
- Identification and estimation of factors which can be used to estimate past emissions
- Estimation of present and historical emissions and preparation of other data bases
- Spatial analysis by air quality modeling, emission-density plotting and comparison with available air quality data
- Identification of high and low exposure data.

As mentioned earlier, the extent of information on ambient concentrations and emissions for each carcinogen determines the approach to be taken for identification of high and low exposure areas. The extent of information available for 23 carcinogens is described below. The remainder of this section discusses air quality models and their input requirements. The other steps outlined above are described in Section 4 as they relate to each specific chemical selected for exposure analysis.

EXTENT OF AVAILABLE INFORMATION

The extent of information available on emissions and air quality has to be examined before an approach can be selected for exposure analysis. The amount of information varies considerably for the 23 carcinogens. For some, an extensive analysis is possible, while on the other extreme, virtually no information exists for many others. An attempt is made here to describe the extent to which information is available for selected chemicals with specific reference to types of sources, emission factors,

air quality measurements, and atmospheric reactivity. The following discussion addressing these specific points for each chemical is by no means comprehensive, yet it highlights availability as well as gaps in the data bases.

Types of Sources

One important consideration here is the nature of the emission sources. For estimation of emissions and subsequent analysis, it is useful to distinguish between "direct" sources of a carcinogen, those resulting from its production or use, and "indirect" sources, those in which the carcinogen is emitted as a result of some other process (i.e., coal or oil combustion, petroleum refining, waste disposal, etc.). These direct and indirect sources can be further classified into point sources, which represent identifiable sources at a stationary location, or area sources, which are clusters of mobile or small stationary sources.

The estimated percentages of emissions for each carcinogen from each of the four classifications of sources are shown in Table 2. Although in many cases these are crude estimates, they give a general idea of the relative magnitude of different sources. For example, sources of acrylonitrile emissions consist only of the processes by which acrylonitrile is manufactured or used. On the other hand, in evaluating exposure to benzene, production and various uses of benzene must be considered. However, even more important in the case of benzene are inadvertent sources such as automobile evaporative losses and exhaust, gasoline handling, etc., which do not involve either production or a direct use of benzene.

Emission Factors

Emission factors, when combined with appropriate operating data such as amount of fuel burned per hour or amount of chemical processed per year, will yield estimates of emissions. Thus, if operating data are available, the availability of emission factors for all sources and their quality will determine the completeness and quality of emission estimates.

Table 3 summarizes information on emission factors using the terms "partial" and "limited" to describe the completeness of emission factor data and the terms "source tests," "engineering estimates," and "crude estimates" to describe the method of determination, or quality, of these factors. "Source tests" include direct measurement techniques such as optical emission spectroscopy, neutron activation, etc., and "crude estimates" indicate either that rough calculations have been made by methods such as material balances or else that a wide discrepancy exists between values given in different references. The term "source tests" does not appear in Table 3, since source testing was not used to determine emission factors for all sources of a given carcinogen. The term "varying reliability" is used for carcinogens which have emission factors of more than one quality.

TABLE 2. ESTIMATED EMISSIONS BY TYPE OF SOURCE
(in percent of total emissions for each carcinogen)

Chemical (Reference)	Direct*		Indirect†	
	Point	Area	Point	Area
Benzene (2)	18	0	0	82
Vinyl chloride (3)	< 100	0	unknown	0
Acrylonitrile (4)	100	0	0	0
Nickel & compounds (5)	small	0	< 59	< 41
Ethylene dibromide (6)	2	98	--‡	--‡
Asbestos (5)	98	1	< 1	< 1
Chromium & compounds (5)	77	0	18	5
BaP (5)	0	0	12	88
Arsenic & compounds (5)	2	33	64	< 1
Benzidine (4)	100	0	0	0
Ethylene oxide (4)	100	0	0	0
Carbon tetrachloride (4)	unknown#	small	0	0
Trichloroethylene (4)	< 100	0	small	0
Chloroform (4)	unknown#	0	0	unknown **
Vinylidene chloride (4)	< 100	0	small	0
Cadmium & compounds (5)	< 1	< 1	< 98	unknown††
Dimethyl sulfate (4)	100	0	0	0
Chloromethyl methyl ether (4)	unknown#	0	0	0
Formaldehyde (4)	unknown#	0	unknown ‡‡	unknown§§
Tetraethyl lead (4)	unknown#	unknown§§	0	0
Pentachlorophenol (4)	unknown#	unknown##	0	0
Polychlorinated biphenyl (4, 7)	10***	22†††	68‡‡‡	0
Beryllium & compounds (5)	6	0	94	0

* Production or use of a chemical constitutes a direct source for that chemical.
† Indirect source--sources other than those involving production or use.
‡ None known.
§ Direct-point sources consist of asbestos mining; other types of sources may have been underestimated since their estimates of emissions are not available.
# Production and use, emissions unknown.
** Chlorination of water, emissions unknown.
†† Incineration of plastics, emissions unknown.
‡‡ Petroleum refining, emissions unknown.
§§ Vehicle exhaust, emissions unknown.
Used as fungicide and bactericide for treating wood and textiles, emissions unknown.
*** Production banned in 1970; since then, production has declined.
††† Evaporation of plasticizer in paints and coatings.
‡‡‡ Spills, leaks and disposal of PCB used in transformers.

TABLE 3. EXTENT AND QUALITY OF INFORMATION ON EMISSION FACTORS

Chemical	Emission Factors		Reference
	Availability	Quality	
Benzene	limited	engineering estimates	8
Vinyl chloride	partial	engineering estimates	3
Acrylonitrile	partial	crude estimates	4
Nickel & compounds	partial	varying reliability	4
Ethylene dibromide	limited	crude estimates	6
Asbestos	limited	unknown	5
Chromium & compounds	partial	varying reliability	5
BaP	partial	varying reliability	5
Arsenic & compounds	partial	varying reliability	5
Benzidine	none	--	
Ethylene oxide	limited	engineering estimates	4
Carbon tetrachloride	limited	engineering estimates	4
Trichloroethylene	limited	engineering estimates	4
Chloroform	limited	crude estimates	4
Vinylidene chloride	partial	engineering estimates	9
Cadmium & compounds	partial	varying reliability	4
Dimethyl sulfate	none	--	
Chloromethyl methyl ether	none	--	
Formaldehyde	limited	engineering estimates	4
Tetraethyl lead	none	--	
Pentachlorophenol	none	--	
Polychlorinated biphenyls	none	--	
Beryllium & compounds	partial	varying reliability	4

The term "partial" implies that approximately 75 percent or more of the total emissions can be estimated with the available emission factor.

Air Quality Data

Ambient air quality measurements are extremely important in assessing the performance of air quality models to predict ambient concentrations. Although criteria pollutants, such as particulates, sulfur dioxide, etc., are routinely measured at several sites within an urban or rural area, only very few of the chemicals listed are monitored regularly. The few carcinogenic substances for which ambient air quality data are available include elemental metals such as nickel, cadmium, chromium, lead, etc. The particulate samples collected at the National Air Surveillance Network (NASN) sites are routinely analyzed for these metals. Several urban and nonurban sites are included in NASN, and this sampling program, which began in 1966, provides useful data for trend analysis. However, for most organic chemicals, there is very limited or no air quality information available. Table 4 summarizes available air quality data; details are reported elsewhere (4).

Atmospheric Reactivity

Reactivity of a chemical in the atmosphere determines whether that chemical will persist, be converted into more harmful substances, or will decay and be transformed into innocuous material. Information on this aspect of the 23 selected carcinogens is generally insufficient for any extensive analysis of atmospheric transformation. However, available information could be useful for determining gross behavior of the chemical emitted into the atmosphere. Data presented in Table 5 are extracted from reference 4.

MODELING

As indicated in the previous section, emissions of some of the carcinogens occur from a limited number of sources, while emissions of other carcinogens, especially those resulting from various combustion processes, involve large numbers of sources. In order that both types of situations could be examined, two diffusion models were selected. EPA's single source (CRSTER) model was selected for small numbers of point sources having the same geographical location, and the Air Quality Display Model (AQDM) was used for multiple sources.

Both AQDM and CRSTER have been extensively used for some of the criteria pollutants, especially particulates and sulfur dioxide. Their use for estimation of atmospheric transport of specific carcinogens has not been reported. One of the aims of this task was to develop a methodology for determining carcinogen exposure. We have used the two established models to see if these are adequate for a first-generation diffusion analysis of carcinogens.

TABLE 4. EXTENT OF AVAILABLE AIR QUALITY INFORMATION

Chemical	Available ambient air quality data
Benzene	several urban sites, limited period of measurements *
Vinyl chloride	source-oriented, limited period of measurements
Acrylonitrile	none
Nickel & compounds	NASN †
Ethylene dibromide	source-oriented, limited period of measurements
Asbestos	source-oriented, limited period of measurements
Chromium & compounds	NASN
BaP	NASN
Arsenic & compounds	NASN
Benzidine	none
Ethylene oxide	none
Carbon tetrachloride	limited number of sites, limited period of measurements
Trichloroethylene	limited number of sites, limited period of measurements
Chloroform	limited number of sites, limited period of measurements
Vinylidene chloride	none
Cadmium & compounds	NASN
Dimethyl sulfate	none
Chloromethyl methyl ether	none
Formaldehyde	NASN data for 1967, otherwise limited
Tetraethyl lead	no specific data, limited measurements for elemental lead
Pentachlorophenol	none
Polychlorinated biphenyls	source-oriented measurements for a single source
Beryllium & compounds	NASN, air quality levels tend to be near lower discriminatory limits of analytical techniques

* Limited period of measurement implies less than 1 year of continuous measurements.

† National Air Sampling Network.

TABLE 5. ATMOSPHERIC REACTIVITY

Carcinogen	Half-life period	Remarks
Benzene	3 days (reaction with OH radical)	reacts slowly with oxidizing materials
Vinyl chloride	∿3 days (OH radical) ∿3 days (ozone)	
Acrylonitrile	not known	reacts with oxidizing materials
Nickel & compounds	not known	nickel carbonyl decomposes quickly; no data on other compounds
Ethylene dibromide	not known	reacts with oxidizing materials; decomposes by photochemical degradation
Asbestos	stable	subject to reentrainment
Chromium & compounds	not known	no data
BaP	< 1 day (degradation of BaP on surface of soot particle in presence of sunlight)	much longer for BaP present inside the particle or in absence of daylight
Arsenic trioxide	stable	
Benzidine	4 days (RO_2) 1 day (O_3) 1 day (OH)	can be diazotized and oxidized
Ethylene oxide	not known	undergoes reduction
Carbon tetrachloride	> 10 years	inert
Trichloroethylene	not known	photochemical degradation by reductive chlorination
Chloroform	1 to 2 months (OH radical in the troposphere)	highly reactive in troposphere; undergoes thermal reactions
Vinylidene chloride	several hours	quite reactive and believed short-lived in the atmosphere
Cadmium & compounds	not known	no data
Dimethyl sulfate	1170 hours (oxidation by OH radical) 1 to 2 hours (hydrolysis)	

(continued)

TABLE 5 (cont'd)

Carcinogen	Half-life period	Remarks
Chromethyl ethers	BCME: < 1 day (moist air) < 10 days (OH radical) CMME: < 1 day (moist air)	some variations in half-lives are reported by different sources
Formaldehyde	2 - 3 hours	photochemically reactive, but may be a significant contribution to smog in the atmosphere
Tetraethyl lead	not known	undergoes decomposition when exposed to sunlight
Pentachlorophenol	not known	no data
Polychlorinated biphenyls	not known	photochemical degradation by reductive chlorination
Beryllium oxide & other beryllium compounds	not known	no data

Uncertainties in estimating atmospheric transport of substances by diffusion modeling are well recognized (10, 11). Similarly, due to uncertainty in emission factors data, estimation of emissions is also subject to potentially large errors. Despite these limitations, it was felt that if sufficiently complete input information is available and if some actual measurements of ambient air concentrations are available for verification of the results of the model, the uncertainty in the results could be minimized.

For both models, AQDM and CRSTER, preparation of input data was mostly analogous to input for criteria pollutants. One significant deviation for their use is estimating past carcinogen exposures was in the selection of representative time periods for meteorological data (discussed on page 15). Brief descriptions of the two models follow.

AQDM (12)

The computer program used in AQDM is based on the Gaussian diffusion equation which describes the spreading, or diffusion, of a plume as it is transported downwind from an elevated, continuously emitting point source. The model is utilized here to compute annual, arithmetic-averaged, ground-level pollutant concentrations resulting from specified point and area sources. The model calculates the effects of each source on each receptor for the observed combinations of wind direction, wind speed, and stability class. The relative frequency of occurrence for each combination is then included as a factor, and the resulting data are summed for each receptor over all combinations and all sources. The plume is assumed to be normally distributed about its center line (i.e., a Gaussian distribution) in the vertical direction and distributed as a linear function of crosswind distance in the crosswind direction. The required input includes the following.

Receptor Data--

Up to 225 receptor locations corresponding to the intersections in a horizontal grid pattern having equidistant rectangular coordinate spacing are included. A limited number of nongrid receptors can be included.

Point and Area Source Data--

For each point source the location, average annual emission rate (tons/day), and exhaust stack parameters must be specified. The stack parameters (physical stack height, stack exit diameter, effluent exit velocity, and effluent temperature) are used to obtain the effective height of release (i.e., the height at which the plume becomes horizontal) for use in the diffusion calculations. If the stack parameters are not known, an effective stack height value may be used. For each area source (assumed square in shape) the area, centroid location, average annual emission rate, and effective height of release must be input.

Stability Wind Rose Data--

This data base gives the relative frequency of occurrence for each wind direction, wind speed class, and stability category combination as observed for the region and time period of interest. To prepare this meteorological input, a computer program called STAR (STability ARray), which generates frequencies of wind direction by speed classes for each stability category, is used in conjunction with meteorological surface elevations.

Mixing Depth--

The mixing depth is defined as the depth above the surface through which the pollutants are mixed. Since this depth varies greatly from season to season, day to day, and diurnally, it is only practical to account for major changes. The program uses a single input value, the annual average afternoon mixing depth, and modifies it according to the stability class.

CRSTER (13)

CRSTER is the single source model designed to calculate ambient concentrations of pollutants emitted from multiple elevated stacks located at a single location. This model is also based on the Gaussian plume equation and uses empirical dispersion coefficients. As in AQDM, computations include adjustments for plume rise and limited mixing height. However, unlike AQDM, the effect of terrain is considered in CRSTER.

Hourly pollutant concentrations are computed in CRSTER from measured hourly values of wind speed and direction and estimates of atmospheric stability and mixing height. Concentration estimates are made for 180 receptors (36 radial directions and five ring distances) surrounding a plant location. Input data required are basically similar to those listed for AQDM with the addition of receptor elevations relative to the source. Actual hourly meteorological data are required instead of frequency distribution used by AQDM. Since the number of sources is limited in this model and computation time required is small, it offers greater flexibility.

Selection of Time Span of Meteorological Data

The primary aim of air quality modeling in this project was to estimate past exposures, specifically, to estimate concentrations over a period of 20 to 30 years to identify high and low exposure areas. An idealized approach for estimation of past exposures would be to model concentrations for each year during this timespan, which represents the latent period for cancer. The obvious drawback of this approach was that, even though meteorological data for each year were available, year-to-year changes in emission rates were not expected to be available for any carcinogen. Consequently, it was evident that a more limited timespan for meteorological data could be used without significantly sacrificing the accuracy of results.

In the case of AQDM used for the Detroit pilot study area (Section 4), a 5-year average of meteorological frequency distribution was employed as recommended by Doty et al. (14). CRSTER was not used for the Detroit area but a different and logically more attractive approach in selection of time span of meteorological data was possible for the single source model. Usefulness of this approach is limited to the purpose of the task, i.e., to find high and low exposure areas.

The approach consisted of identifying a year which, when used as input base for meteorological data, the model would effectively simulate extreme conditions (high or low) during the 20-year period. To identify a year for such an extreme case, first the CRSTER model was used to draw isopleths for a certain constant concentration for each year from 1957 to 1976. The data on emissions and stack parameters were kept the same for all 20 computer runs. Thus, the effect of emissions and stack parameters was controlled and differences in the shapes of 20 isopleths represented the influence of meteorological conditions alone. Next, the iscpleths for individual years were combined to give a "minimum area" composite isopleth, the rationale being that during any of the 20 years, average annual concentrations inside the composite isopleth will always be greater than the isopleth concentration. By properly choosing a concentration for drawing isopleths, the composite isopleth would then represent the outer boundary of a high exposure area for the time period of analysis. Lastly, for selecting a year, the isopleths for individual years were compared with the composite, and a year for which an individual isopleth most closely matched the shape of the composite was selected.

An example of a composite isopleth based on isopleths for 3 years representing the period 1962-64 is shown in Figure 1. The inputs to CRSTER for each year were identical except for the yearly meteorological data (emission rate, 1 g/s; stack height, 100 m; diameter, 1 m; exit velocity, 1 m/s; and temperature, 350 K). The isopleths were drawn for an arbitrary but constant concentration of 15 concentration units. The three isopleths were superimposed on each other and an inside boundary representing a minimum area was plotted. Any point within the composite (shaded area in Figure 1) would, by definition, have an annual average concentration for each of the 3 years which is greater than or equal to the isopleth concentration.

The process illustrated above for the period 1962-64 was repeated for the entire 20-year span. Figure 2 shows the 20-year composite isopleth for Detroit. When the isopleths for individual years were compared with this composite, the isopleth for year 1965 matched most closely with the composite (Figure 3). The meteorological data for 1965 used as input to CRSTER would thus give isopleths for identifying "high exposure" areas. For identifying areas which area definitely lower than the isopleth concentration, a similar process was repeated by drawing a composite based on a "maximum area" isopleth.

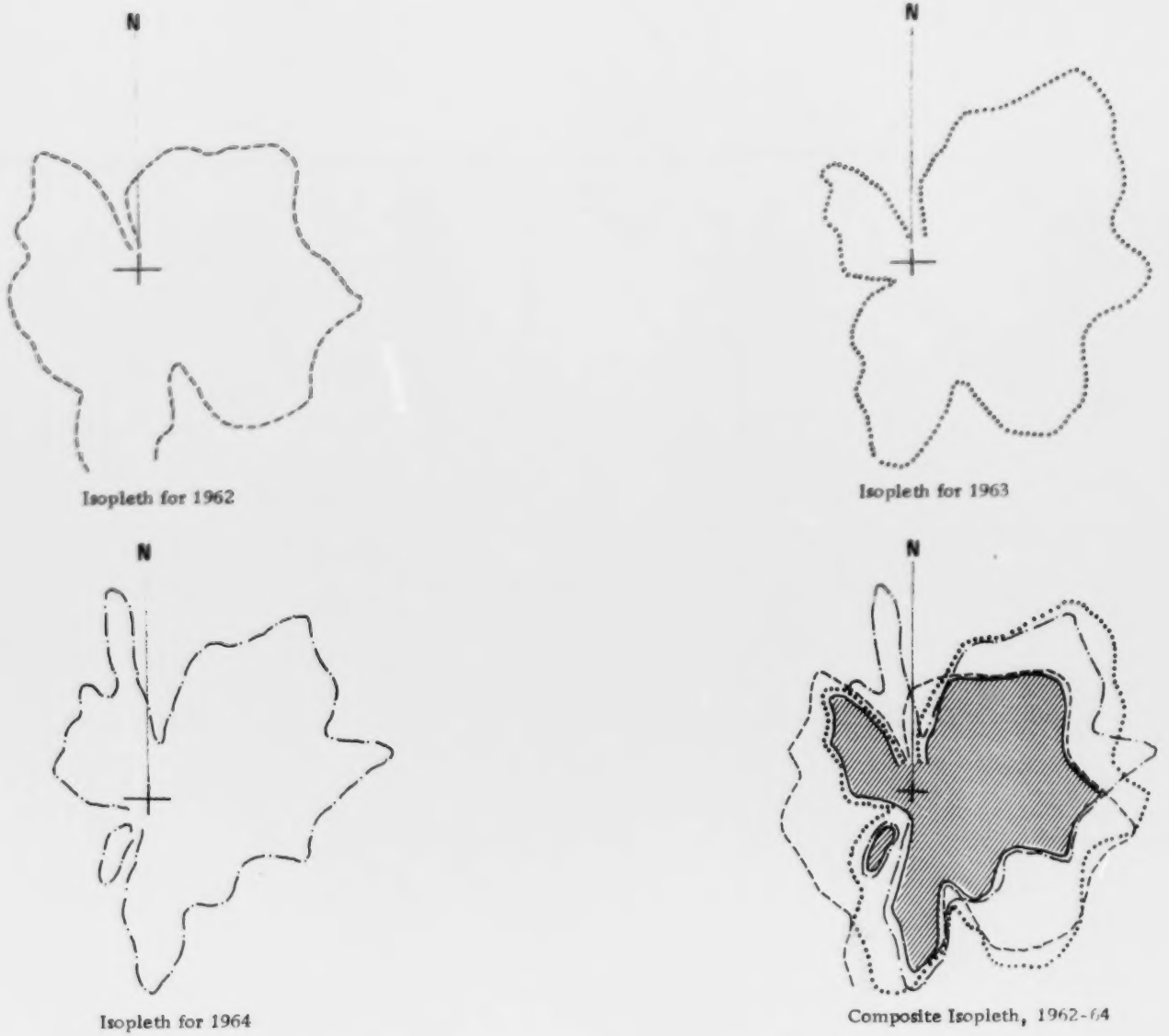

Figure 1. An example of a composite isopleth.

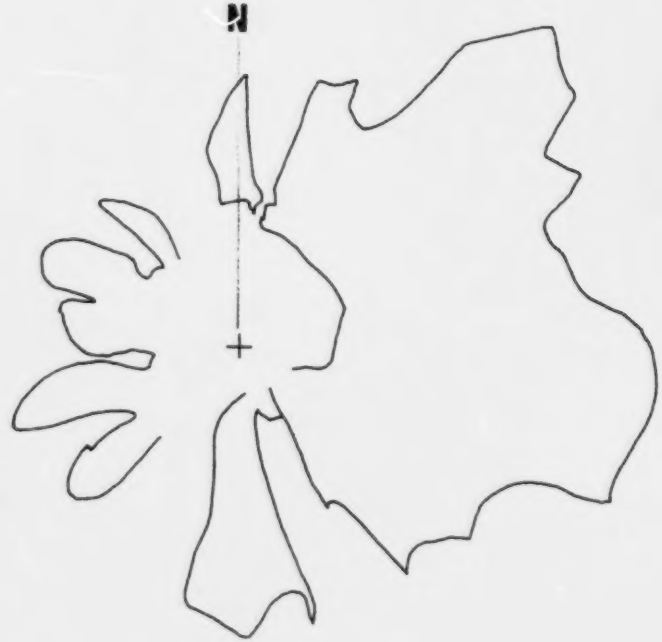

Figure 2. The minimum area composite isopleth based on isopleths for individual years during 1957-76.

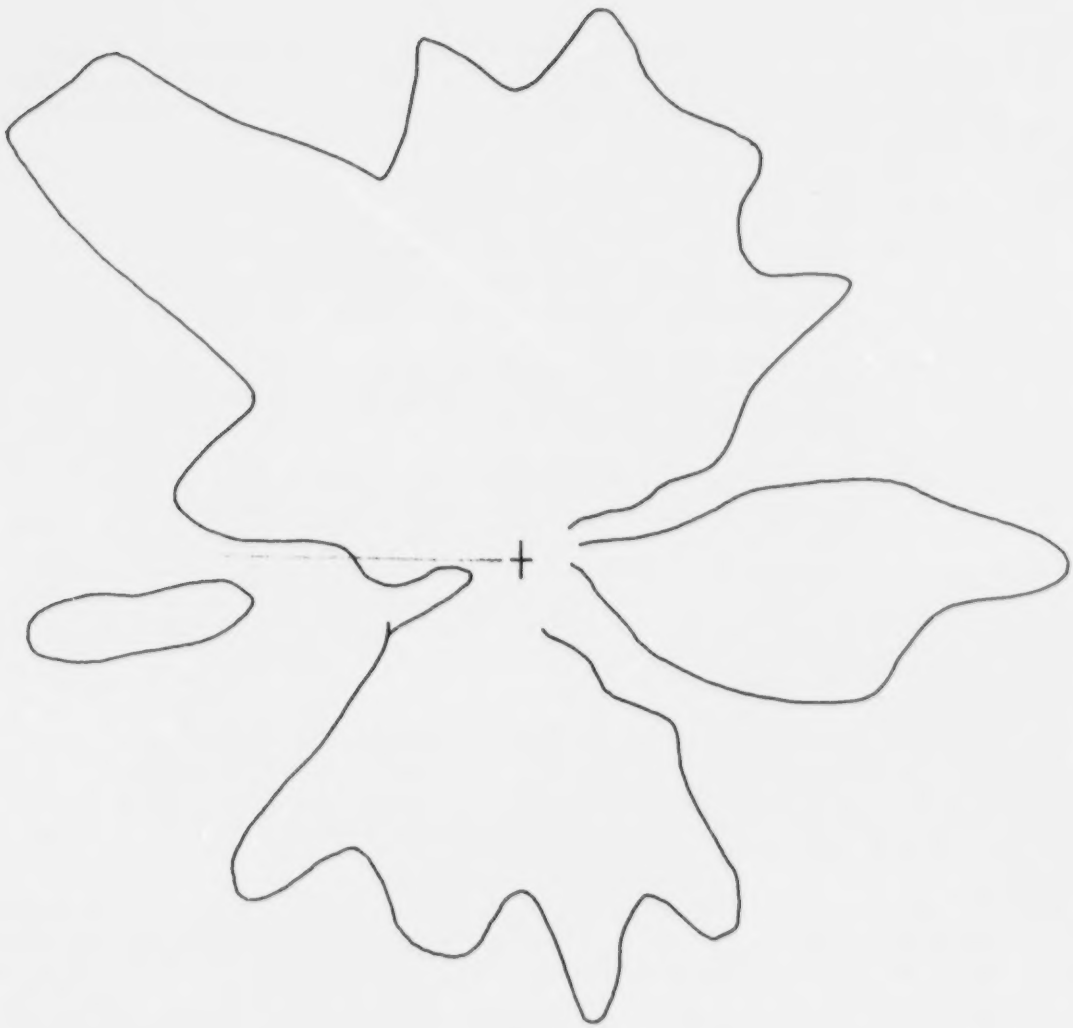

Figure 3. Isopleth for 1965.

SECTION 4

CARCINOGEN EXPOSURE ANALYSIS-- DETROIT PILOT STUDY AREA

The Detroit metropolitan area (Figure 4), consisting of Macomb, Oakland, and Wayne Counties, was selected as the first pilot study area for carcinogen exposure analysis and subsequent epidemiological survey. The following criteria were used in the selection of the pilot study area:

- The study area must include a county or counties which have significantly high mortality rates for individual cancer sites. In order to eliminate counties which have high cancer rates due to occupational exposure, the rates must be high for both males and females.

- To facilitate statistical analysis, in addition to significantly high rates, the absolute number of deaths should be large.

- The county with high cancer rates should have an adjacent county which has rates significantly lower than national averages. Inclusion of counties with extreme rates would permit selection of population samples from high carcinogen exposure areas as well as low exposure areas for examination of association between environmental exposure to a carcinogen and increased cancer risk.

- In order that up-to-date information is available, the potential study area must be included in either the Third National Cancer Survey or the continuing cancer Surveillance Epidemiology and End Results (SEER) reporting program.

Only the Detroit, Michigan and Pittsburgh, Pennsylvania metropolitan areas met these criteria. Subsequently, the Detroit metropolitan area was selected as the first pilot study area.

SELECTION OF CARCINOGENS FOR EXPOSURE ANALYSIS

From the list of 23 carcinogens selected in this study (1), substances which have potential for emissions in the Detroit area were identified. The potential for emissions was determined based on emissions inventory, production and use of a chemical, or air quality information. Table 6 identifies carcinogens which may be emitted in significant quantities in the Detroit area. Next, for these chemicals, the adequacy of emission factor data was

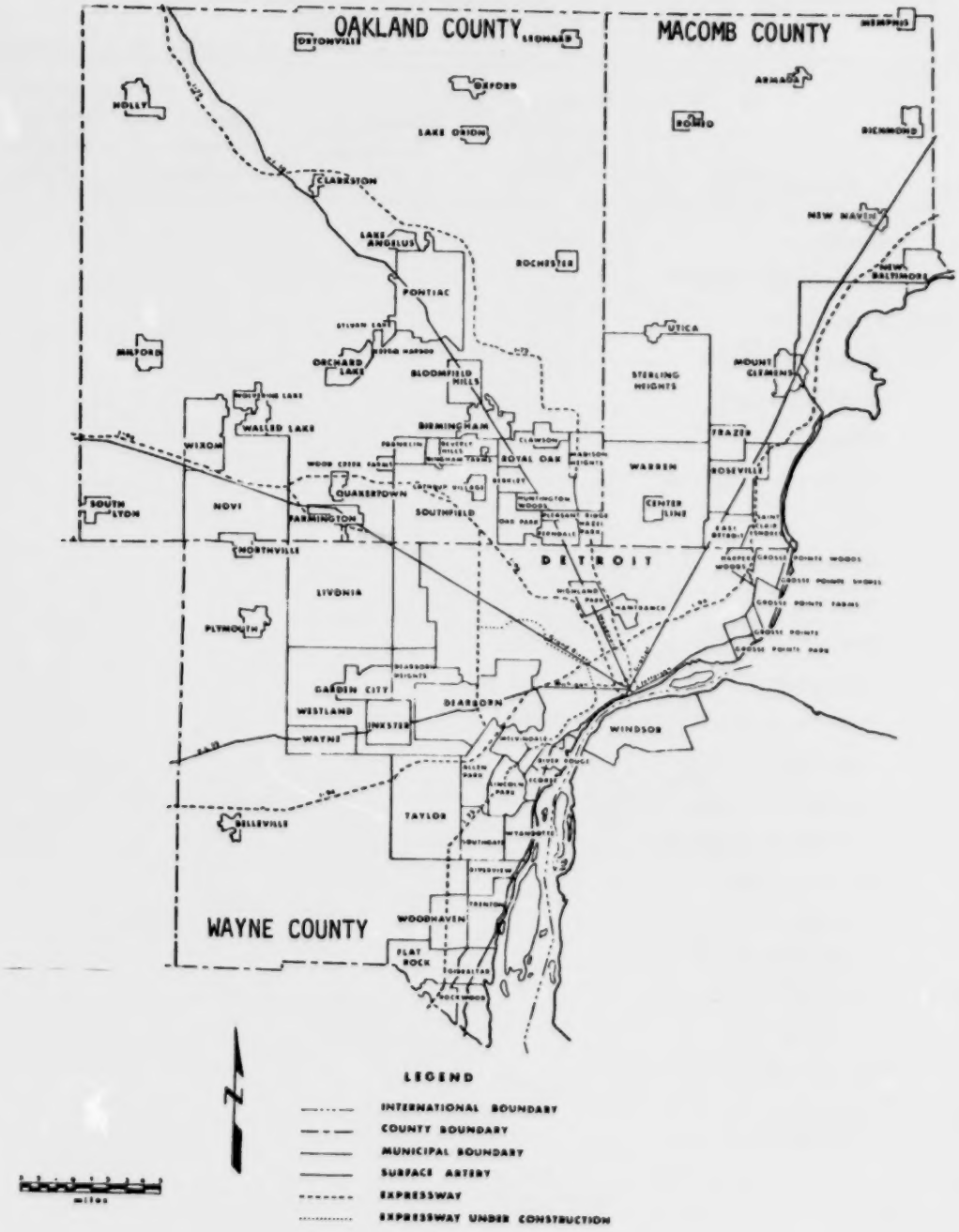

Figure 4. Detroit metropolitan study area.

TABLE 6. SELECTION OF CARCINOGENS FOR EXPOSURE ANALYSIS IN THE DETROIT PILOT STUDY AREA

Number	Chemical Name	Potential for Significant Emissions in Detroit	Adequacy of Emissions Data	Exposure Analysis by Modeling	Exposure Analysis by Emissions Density
1	Benzene	DCP*			
2	Vinyl chloride monomer				
3	Acrylonitrile				
4	Nickel & compounds	AQ†	X		X
5	Ethylene dibromide				
6	Asbestos				
7	Chromium & compounds				
8	BaP	DCP‡, AQ	X	X	
9	Arsenic trioxide				
10	Benzidine				
11	Ethylene oxide	DCP			
12	Carbon tetrachloride				X
13	Trichloroethylene	MDNR§	X		
14	Chloroform				
15	Vinylidene chloride				
16	Cadmium & compounds	AQ	X		X
17	Dimethyl sulfate				
18	Chloromethyl & bischloromethyl ether				
19	Formaldehyde	DCP			
20	Tetraethyl lead				
21	Pentachlorophenol (PCP)				
22	Polychlorinated biphenyl (PCB)				
23	Beryllium & compounds	AQ	X		

* Directory of Chemical Producers (15)

† Air Quality Data (16)

‡ As a by-product of coke production

§ Michigan Department of Natural Resources point-source data system

examined. Insufficient emissions or source data existed for three organic chemicals: benzene, ethylene oxide and formaldehyde. Further, no information on ambient air concentrations was available for these three chemicals. Consequently, they were excluded from further consideration.

Limited data on emission factors were available for nickel, BaP, cadmium, and beryllium. BaP offered greatest potential for an in-depth analysis since emission factors data were more extensive than others and some historical air quality information was available. Ambient concentrations of BaP were simulated by air quality modeling. Nickel and cadmium had comparatively limited air quality and emission factors data, and thus were not included for extensive analysis similar to BaP. Emission densities were calculated for nickel and cadmium. In the case of beryllium, even though emission factors and air quality data were available, levels of ambient concentration were very low--near its detection limit--and thus it was not included in the exposure analysis.

For trichloroethylene, emission factors per se were not available, but the Michigan Department of Natural Resources (MDNR) emissions data system (discussed later in this section) listed the amount of trichloroethylene used as annual makeup solvent in each establishment. All makeup solvent was assumed to be emitted. Since no air quality data for trichloroethylene were available, only an emission density analysis was performed.

BENZO-A-PYRENE

BaP is a component of a family of compounds known as polycyclic organic matter. It has been suspected for approximately the last 40 years of being carcinogenic to humans (17). Possibly for this reason, BaP has been studied more extensively than many other carcinogens.

One of the earliest studies on BaP ambient concentrations in the United States was done by Sawicki et al. (18). Detroit was included in this study as one of the nine urban sites where BaP concentrations were measured for a 12-mo period beginning in July 1958. Routine measurements of ambient BaP concentrations began in 1966 at the National Air Surveillance Network's (NASN) 126 urban and 22 nonurban stations in the United States. A trend analysis of BaP concentrations prevalent during 1966-70 showed a downward trend (19, 20). As shown later in the discussion on BaP air quality data, this trend does not agree with measurements taken in Detroit since 1971.

Contributions to ambient BaP levels due to automotive exhaust (21) and coke oven emissions (22) have been analyzed. Fewer studies exist on concentrations of BaP in effluent streams from specific sources (23, 24).

Emissions

Sources--

A schematic diagram of the general procedure followed in estimation of BaP emissions for input to AQDM is given in Figure 5. It involved parallel considerations of sources and emission factors. Sources of BaP and their nationwide estimates of emissions are given in Table 7. Estimates I and II in Table 7 represent the information available at the start of BaP exposure analysis for the Detroit area and these were used in the initial selection of type of sources to be included for estimation of emissions. Emission estimates under Estimate III were available after emissions and air quality computations were completed.

Sources included in the initial considerations were:

- Coal-fired utility and industrial boilers and industrial furnaces
- Oil-fired utility and industrial boilers
- Gas-fired utility and industrial boilers
- Petroleum refining
- Coke production
- Asphalt production
- Incineration
- Automobiles.

To include the above categories of sources, data on both point and area sources were necessary. Initially, point-source data were obtained from the National Emissions Data System (NEDS). NEDS data appeared to be incomplete and a contact with the State of Michigan Department of Natural Resources revealed that Michigan has its own source and emissions data system. This data system contains information quite similar, but not identical, to that in NEDS. For identification of source categories, instead of the Source Classification Codes (SCC) used by NEDS (28), the Michigan system contains a list of equipment. The MDNR list of sources, their codes, and other information are given in Appendix A. Sources selected for estimation of BaP emissions are listed in Table 8.

In contrast to point sources for which data are available on an individual source basis, the smallest geographic unit for which area-source data exist is the county. The county data have to be disaggregated and apportioned to smaller areas to provide an adequately detailed input for modeling. Since coal-fired residential furnaces account for over one-third of nationwide BaP emissions, a careful consideration of area sources

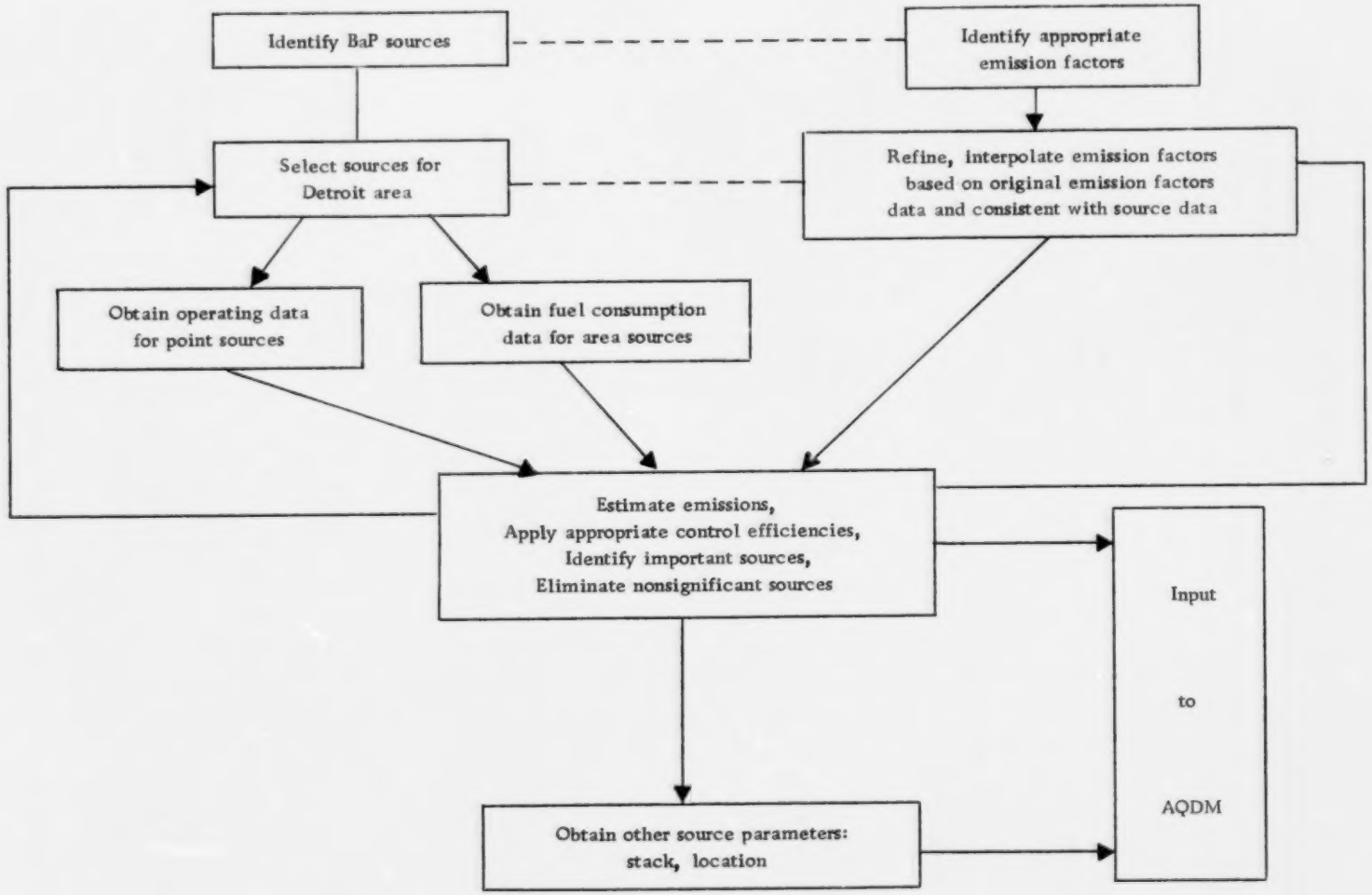
Identify BaP sources
Identify appropriate emission factors
Select sources for Detroit area
Refine, interpolate emission factors based on original emission factors data and consistent with source data
Obtain operating data for point sources
Obtain fuel consumption data for area sources
Estimate emissions,
Apply appropriate control efficiencies,
Identify important sources,
Eliminate nonsignificant sources
Input to AQDM
Obtain other source parameters: stack, location

Figure 5. A schematic diagram for estimation of BaP emissions for input to AQDM.

TABLE 7. NATIONWIDE ESTIMATES OF BaP EMISSIONS (tons/yr)

Source	Estimate I*	Estimate II†	Estimate III‡	Detroit Pilot Study Area
Combustion				
Coal fired				
power plants		0.6	0.46	Included
industrial boilers	7	8.6	0.057	Included
residential furnaces		410.0	26.0	Included
Other solid fuel				
domestic store	25			No data
residential fireplaces			40.0	No data
Oil fired				
industrial boilers			0.37	Included but not significant
comm/inst boilers		1.5	19.0	
residential furnaces			0.98	Not included
Gas fired				
industrial boilers			0.019	Included but not significant
comm/inst boilers		1.2	0.4	
residential furnaces			0.31	Not included
Industrial Processes				
Petroleum catalytic cracking				
fluid	7	0.22	0.00023	Included
Thermofore		13.0	0.0012	No sources
Houdriflow		5.6	0.0048	No sources
Coke production	170			Included
Asphalt production				
saturators			0.0044	
air blowing		0.00005	0.0044	Included but not significant
hot road mix		0.00005	0.0044	
Other industrial processes				
iron & steel sintering			0.63	Not included
carbon black production			0.088	Not included

(Continued)

* Estimate I: Preferred Standards Path Report for Polycyclic Organic Matter (25)

† Estimate II: Goldberg, A.J. (26)

‡ Estimate III: Energy and Environmental Analysis, Inc., Draft Report (27)

TABLE 7 (Cont'd)

Source	Estimate I*	Estimate II †	Estimate III ‡	Detroit Pilot Study Area
Incineration/Open Burning/Fires				
Incinerators				
Municipal	3	0.1	0.027	Included
Commercial		4.8	2.1	Included
Open burning				
Municipal refuse	10	4.8		No data
Auto components	25	5.7		
Grass/leaf		4.8		
Agricultural & forest fires				
Bagasse boilers	11			No sources
Forest fires				
Coal refuse burning	310		310	No data
Mobile Sources				
Automobile (gasoline)	11	8.6	16	Included but not significant
Automobile (diesel)		2.0	0.0009	
Trucks (diesel)			0.13	Not included
Rubber tire wear	11		11	Not included

TABLE 8. SOURCES SELECTED FOR ESTIMATION OF BaP EMISSIONS IN THE DETROIT AREA

Process	Equipment	Equipment code*
Open burning	Open burning	0001
Incinerators	Single chamber	0005
	Multiple chamber	0006
	Flue fed	0007
	Controlled Air	0008
	Conical Tee Pee	0009
	Liquid waste	0010
	Municipal	0011
	Multiple hearth—sewage sludge	0012
	Fluidized bed—sewage sludge	0013
	Other type	0014
Heating	Warm air furnaces—coal fired	0016
Coal burning boilers	Hand fired	0019
	Underfed stoker	0020
	Spreader stoker	0021
	Other type stoker	0022
	Pulverized corner fired	0023
	Pulverized other type	0024
	Cyclone type	0025
Turbine generators	Gas turbine—gas fired	0026
	Gas turbine—oil fired	0027
Asphalt blowing	Blowing still	0300
Coke production--by-product process	Coke battery	0700
Petroleum refining--catalytic cracking	Fluid cracking unit	0980

* MDNR point-source system given in Appendix A.

was necessary. An area-source data file used in air quality maintenance planning for metrpolitan Detroit by MDNR was available but it contained aggregated criteria pollutant emissions which were not directly usable in computation of BaP emissions (29). EPA has developed a computer-aided gridding procedure to apportion fuel-usage and other data for counties to smaller areas. This system, called Computer Assisted Area Source Emissions (CAASE) (30), was not fully operational for general application when this study was being performed. However, 1970 data for the Detroit study area were available as test-case results of CAASE (31). The area-source file for the three-county area consisted of 2024 grids with sizes ranging from 1 to 100 km^2 (Figure 6) and for 54 categories (Table 9). Categories No. 2 and 27, representing residential fuel combustion and automobile gasoline usage, were selected for initial evaluation. In order to reduce computer time required for modeling, grids were aggregated and the total number of grids was reduced significantly. The revised grids are shown in Figure 7.

Emission Factors--

Work done by Hangebrauck et al. (24, 32) and von Lehmden (23) provides much of the bases for emission factors summarized in different forms in several references (5, 25, 33, 34). Initial computations for BaP emissions showed source categories such as coal combustion and coke ovens to be important, but asphalt blowing and automobiles were not significant. In the case of coal combustion, the emission factors data were found to be inadequate for different types of coal-fired boilers and their sizes contained in the MDNR point-source data system (Appendix A). Coal consumption was examined by type of boiler and its size in the study area (Table 10). The detailed emission factors data given by Hangebrauck (32) were used to estimate appropriate emission factors for coal-fired boilers and furnaces (Table 11). Table 12 lists BaP emission factors for other sources.

Efficiencies of Control Equipment--

BaP emissions are known to be associated primarily with particles less than 3 μm in size (37). The small-size particles are difficult to control and, depending on the type of control equipment, the efficiencies for smaller sizes could be considerably lower than those for overall particle size distributions. Efficiencies for particle size-range of 0 to 5 μm were used for calculating controlled emissions.

Information on type of control equipment was included in MDNR point-source data. This information was used to obtain control efficiencies for small-size particles (Table 13), with one exception. In the case of coke ovens, the information on control equipment for coke ovens yielded efficiences of 95 to 99 percent for less than 5 μm particles. These were judged to be unrealistically high and were not used. Instead, control efficiency estimates obtained from EPA Region V Office (38) were used in estimation of BaP emissions from coke ovens.

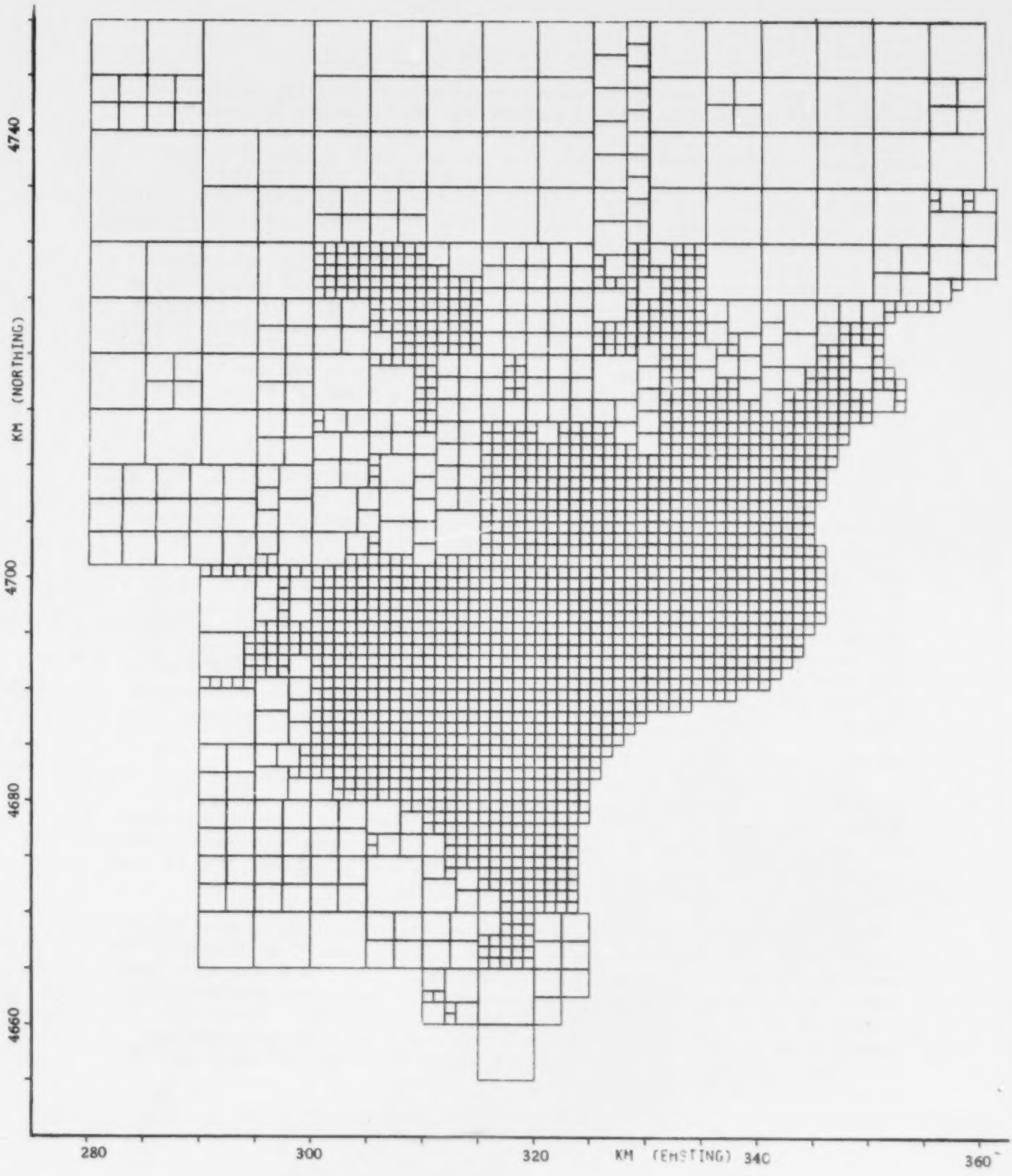

Figure 6. CAASE area source grids for Detroit metropolitan study area.

TABLE 9. CATEGORIES OF AREA SOURCE EMISSIONS*

CATEGORY NUMBER	MAJOR CLASSIFICATION	MINOR CLASSIFICATION
1	RESIDENTIAL FUEL	ANTHRACITE COAL
2	RESIDENTIAL FUEL	BITUMINOUS COAL
3	RESIDENTIAL FUEL	DISTILLATE OIL
4	RESIDENTIAL FUEL	RESIDUAL OIL
5	RESIDENTIAL FUEL	NATURAL GAS
6	RESIDENTIAL FUEL	WOOD
7	COMMERCIAL & INSTITUTIONAL FUEL	ANTHRACITE COAL
8	COMMERCIAL & INSTITUTIONAL FUEL	BITUMINOUS COAL
9	COMMERCIAL & INSTITUTIONAL FUEL	DISTILLATE OIL
10	COMMERCIAL & INSTITUTIONAL FUEL	RESIDUAL OIL
11	COMMERCIAL & INSTITUTIONAL FUEL	NATURAL GAS
12	COMMERCIAL & INSTITUTIONAL FUEL	WOOD
13	INDUSTRIAL FUEL	ANTHRACITE COAL
14	INDUSTRIAL FUEL	BITUMINOUS COAL
15	INDUSTRIAL FUEL	COKE
16	INDUSTRIAL FUEL	DISTILLATE OIL
17	INDUSTRIAL FUEL	RESIDUAL OIL
18	INDUSTRIAL FUEL	NATURAL GAS
19	INDUSTRIAL FUEL	WOOD
20	INDUSTRIAL FUEL	PROCESS GAS
21	ON-SITE INCINERATION	RESIDENTIAL
22	ON-SITE INCINERATION	INDUSTRIAL
23	ON-SITE INCINERATION	COMMERCIAL & INSTITUTIONAL FUEL
24	OPEN BURNING	RESIDENTIAL
25	OPEN BURNING	INDUSTRIAL
26	OPEN BURNING	COMMERCIAL & INSTITUTIONAL FUEL
27	GASOLINE FUEL	LIGHT VEHICLE
28	GASOLINE FUEL	HEAVY VEHICLE
29	GASOLINE FUEL	OFF-HIGHWAY
30	DIESEL FUEL	HEAVY VEHICLE
31	DIESEL FUEL	OFF-HIGHWAY
32	DIESEL FUEL	RAIL LOCOMOTIVE
33	AIRCRAFT	MILITARY
34	AIRCRAFT	CIVIL
35	AIRCRAFT	COMMERCIAL
36	VESSELS	ANTHRACITE COAL
37	VESSELS	DIESEL OIL
38	VESSELS	RESIDUAL OIL
39	VESSELS	GASOLINE
40	EVAPORATION	SOLVENT PURCHASED
41	EVAPORATION	GASOLINE MARKETED
42	MEASURED VEHICLE MILES	LIMITED ACCESS ROADS
43	MEASURED VEHICLE MILES	RURAL ROADS
44	MEASURED VEHICLE MILES	SUBURBAN ROADS
45	MEASURED VEHICLE MILES	URBAN ROADS
46	DIRT ROADS TRAVELED	...
47	DIRT AIRSTRIPS	...
48	CONSTRUCTION LAND AREA	...
49	ROCK HANDLING & STORING	...
50	FOREST FIRES	AREA-ACRES
51	SLASH BURNING	AREA-ACRES
52	FROST CONTROL	ORCHARD HEATERS
53	STRUCTURE FIRES	NUMBER PER YEAR
54	COAL REFUSE BURNING	SIZE OF BANK

* Reference 30

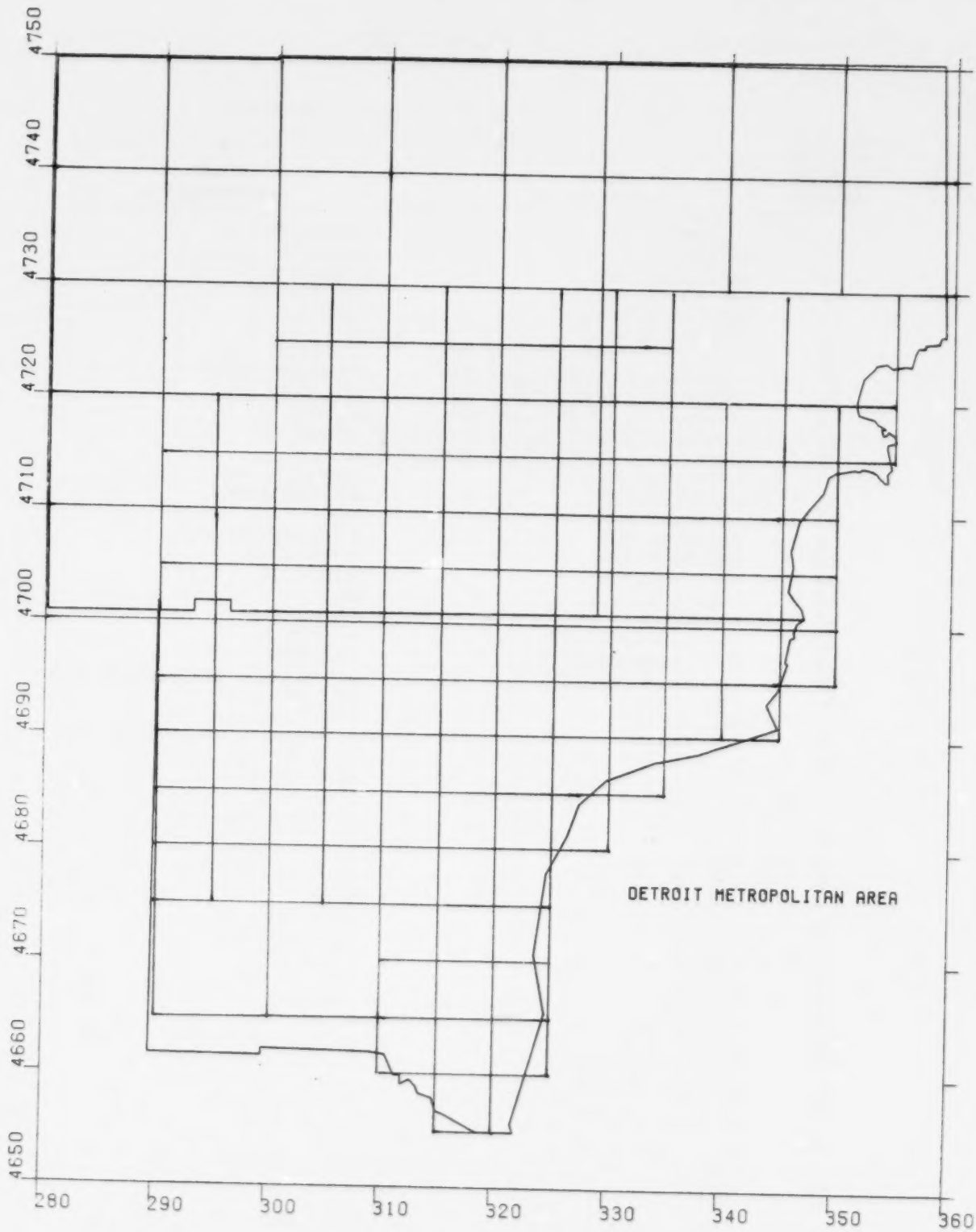

Figure 7. Revised area source grids for BaP emissions.

TABLE 10. 1976 COAL CONSUMPTION FOR THE DETROIT STUDY AREA BY TYPE AND SIZE OF COAL-FIRED BOILERS*

MDNR Equipment Code	Boiler	Annual Coal Consumption in Tons			
		Boiler Size, MBtu/h			
		<1	1 - 10	10 - 100	>100
019	Handfired	400	2,200		
020	Underfeed stoker	400	35,700	36,200	212,700
021	Spreader stoker			114,000	239,900
022	Other stoker		300	68,200	
023	Pulverized corner-fired			3,500	2,349,700
024	Pulverized other type				1,188,500

* Based on Michigan Department of Natural Resources point-source data.

TABLE 11. BaP EMISSION FACTORS FOR COAL-FIRED COMBUSTION UNITS
(Uncontrolled Emissions)

MDNR Equipment Code	Boiler	Emission Factors in g/ton of Coal			
		Boiler Size, MBtu/h			
		<0.2	0.2-10	10-100	100+
019	Hand-fired *	45.0	4.5		
020	Underfeed stoker †	1.1	0.14	0.003	0.003
021	Spreader stoker ‡			0.0018	0.0014
022	Other stoker §		0.0018	0.0018	
023	Pulverized corner-fired #			0.002	0.002
024	Pulverized other type **				0.002
--	Residential coal-fired furnaces ††	23.0			

* For capacities less than 0.2 MBtu/h, three values from Hangebrauck et al. (32) were averaged to give 45 g/ton; this value combined with a scaling factor based on carbon monoxide emission factors (35) was used to compute the emission factor for size 0.2 to 10 MBtu/h.

† Factors of 1.1 g/ton for units smaller than 0.2 MBtu/h and 0.14 g/ton for units of capacities between 0.2 and 10 MBtu/h were calculated by averaging several values from Hangebrauck (32). A factor of 0.003 g/ton presented in the Preferred Standards Path Report for Polycyclic Organic Matter (25) was used for larger capacity stokers.

‡ Factors of 0.0018 g/ton for units smaller than 100 MBtu/h and 0.0014 g/ton for units larger than than 100 MBtu/h were calculated using data from Hangebrauck (32) and assuming a multiple cyclone efficiency of 63 percent for particles less than 5 mm in size.

§ The emission factor was assumed to be the same as for spreader stokers.

A value of 0.002 g/ton was calculated from Hangebrauck (32) assuming a multiple cyclone efficiency of 63 percent.

** A factor of 0.012 g/ton was calculated by averaging 13 values from Hangebrauck (32) using efficiencies of 63 percent for electrostatic precipitators.

†† Calculated assuming equal fraction of <0.2 MBtu hand-fired and underfeed stoker furnaces.

TABLE 12. BaP EMISSION FACTORS FOR SOURCES OTHER THAN COAL COMBUSTION UNITS

MDNR Equipment Code	Source	Emission Factor	Unit
0700	Coke production (36)	2.0*	g per ton of coke produced
0980	Petroleum refining (5)	0.00024*	g per barrel of crude processed
0005-0008	Incineration (5)	0.31	g per ton of refuse burned
--	Automobiles (34)		
	Pre-1964	170	µg per gallon of gasoline
	1968-1970	30	µg per gallon of gasoline
	Post-1970	<11	µg per gallon of gasoline

* Uncontrolled emissions

TABLE 13. SIZE-DEPENDENT EFFICIENCIES OF CONTROL EQUIPMENT*

MDNR Control Equipment Code†	Control Equipment	Particle Efficiency, percent	
		Particles—All Sizes	<5 μm
01	Settling Chamber	58.6	7.5
02	Single Cyclone	65.3	12.0
03-04	Multicyclone		
	Low Efficiency	74.2	25.0
	High Efficiency	93.8	63.0
05-06	Scrubber		
	Low Efficiency	93.6	85.0
	High Efficiency	98.5	93.0
07	Venturi Scrubber	99.5	99.0
10	Fabric Filter	99.7	99.5
13	Electrostatic Precipitator		
	Low Efficiency	97.0	72.0
	High Efficiency	99.0	97.0

* Reference 35

† See Appendix A, Table A-3

Historic Data for Point Sources--

For estimation of BaP emissions during 1956-60, trend data were examined for significant sources such as coke production and coal combustion. No historic data were compiled for two other point-source categories, petroleum refining and incinerators. However, it was assumed for all sources that during 1956-60 no air pollution control equipment was in operation.

Trend data on coal consumption were obtained from the Bureau of Mines (BOM) publications (39). Major categories for coal consumption involving BaP emissions used in BOM publications were electric utilities, coke and gas plants, other industries, and retail deliveries. Since categories in the MDNR data were not directly comparable to BOM categories, the latest sets of data from both sources were analyzed to group categories from MDNR files which are comparable to BOM categories:

BOM Catgegories	MDNR Category Groupings
Electric utilities	All boilers with >60 MBtu/h and with SIC number 4911
Other manufacturing industries	All other boilers with >60 MBtu/h
Retail deliveries	All boilers >60 MBtu/h capacity
Coke and gas plants	Coke

Data on coal consumption for the period 1956 to 1974 for these four categories are given in Tables 14 through 17. The pre-1962 data are given as U.S. totals only, and no separate data for Michigan were available. U.S. totals were apportioned to Michigan based on the average Michigan/U.S. ratio for the post-1962 period. Trends in consumption for Michigan were used for the study area. Procedures for estimation of 1956-60 coal consumption based on the information contained in Tables 14 through 17 and the MDNR data is given in Table 18. The ratios of average annual coal consumption in 1956-60 to 1974, as given in Table 18, were used for estimation of 1956-60 emissions.

Historic Data for Area Sources--

Out of the two categories of area sources. preliminary estimates of emissions based on 1970 data showed that BaP emissions from automobiles were much smaller and practically insignificant compared to emissions from residential fuel combustion. Due to significant decreases in BaP predicted for catalyst equipped automobiles (34), this situation was unlikely to change for 1975-76 even though coal usage also had declined by approximately 50 percent from 1970 to 1975. Consequently, BaP emissions from automobiles were not considered for 1975-76. Automobile emissions during 1956-60 may have been important and were considered in an indirect manner described in the section on modeling.

TABLE 14. COAL CONSUMPTION IN ELECTRIC POWER UTILITIES*

Year	Coal Consumption U.S., thousand tons	Michigan, thousand tons	Ratio: Michigan/U.S., percent
1956	154,983	--†	
1957	157,398	--	
1958	152,928	--	
1959	165,788	--	
1960	173,882	--	
1962	190,833	12,276	6.4
1964	223,032	14,690	6.6
1966	264,202	18,464	7.0
1968	294,739	20,832	7.1
1970	318,921	23,244	7.3
1972	348,612	21,424	6.1
1974	390,068	20,623	5.3

* From Bureau of Mines, Minerals Yearbook, 1960 through 1974 (39).

† No data.

TABLE 15. COAL CONSUMPTION IN MANUFACTURE OF COKE*

Year	Coal Consumption U.S., thousand tons	Michigan, thousand tons	Ratio: Michigan/U.S., percent
1956	101,870	--†	
1957	104,547	--	
1958	75,563	--	
1959	77,354	--	
1960	79,375	--	
1962	72,923	4,249	5.8
1964	86,732	5,309	6.1
1966	93,523	5,012	5.4
1968	89,497	4,914	5.5
1970	94,581	4,942	5.2
1972	86,213	5,378	6.2

* Reference 39

† No data

TABLE 16. COAL CONSUMPTION RELATED TO RETAIL DELIVERIES*

Year	Coal Consumption U.S., thousand tons	Michigan, thousand tons	Ratio: Michigan/U.S., percent
1956	48,670	--†	
1957	35,710	--	
1958	35,620	--	
1959	29,140	--	
1960	30,400	--	
1962	28,188	2,358	8.4
1964	19,615	1,771	9.0
1966	19,965	1,831	9.2
1968	15,224	1,474	9.7
1970	12,072	1,008	8.4
1972	8,748	649	7.4
1974	8,840	351	4.0

* Reference 39

† No data

TABLE 17. COAL CONSUMPTION IN STEEL AND OTHER INDUSTRIES*

Year	U.S. Coal Consumption: Steel Industry, in thousand tons	U.S. Coal Consumption: Other Manufacturing and Mining Industries, in thousand tons†
1956	7,189	93,302
1957	6,938	87,202
1958	7,268	81,372
1959	6,674	73,396
1960	7,378	76,487
1962	7,495	78,766
1964	7,319	82,928
1966	7,117	89,332
1968	5,657	82,637
1970	5,410	82,909
1972	4,850	67,131
1974	6,155	57,819

* Reference 39

† Includes a selected list of representative manufacturing plants.

TABLE 18. FACTORS FOR ESTIMATING 1956-60 COAL CONSUMPTION FOR POINT SOURCES

	Electric Power Utilities	Coke Production	Retail Deliveries	"Other" Industries	
				Other	Steel
1956-60 Average U.S. Coal Consumption (thousand tons)*	161,000	87,700	35,900	82,350	7,090
Average Ratio of Michigan to U.S. (percent)*	6.5	5.7	8.7	--†	--†
1956-60 Annual Michigan Coal Consumption (thousand tons)	10,465	4,999	3,123	82,352‡	7,089‡
1974 Michigan Coal Consumption (thousand tons)	20,623	4,558§	351	57,819‡	6,155‡
Ratio of Average Annual Coal Consumption in 1956-60 to 1974	0.5	1.1	8.9	1.4	1.1

* Based on Tables 14 to 17.

† No separate data for Michigan.

‡ U.S. data.

§ Based on MDNR point-source data.

The residential coal combustion data obtained from CAASE were for 1970. Thus, in addition to estimation of coal consumption in the past, updating the data for 1975-76 was necessary. Two factors were considered in estimation of change in coal usage over a period of time for a county subarea. First trends in coal-burning residential furnaces in the three counties were obtained. The Census of Housing (40) contains information which was used to examine this trend. Secondly, the county trends in coal consumption were adjusted to consider changes in population patterns within a county. This "adjustment" was done based on data on changes in occupied dwelling units for subcounty areas. The following relation was used to estimate the coal consumption for a subcounty area for year YY based on coal consumption data for 1970.

$$CC_{\text{Subcounty, YY}} = CC_{\text{Subcounty, 1970}} \times \left(\frac{CC_{\text{county, YY}}}{CC_{\text{county, 1970}}}\right) \times \left(\frac{DU_{\text{subcounty, YY}}}{DU_{\text{subcounty, 1970}}}\right) \times \left(\frac{DU_{\text{county, 1970}}}{DU_{\text{county, YY}}}\right)$$

$$\text{(subcounty 1970 coal consumption)} \times \left[\left(\begin{matrix}\text{county coal consumption}\\ \text{trend factor}\end{matrix}\right) \times \left(\begin{matrix}\text{subcounty population}\\ \text{shift factor}\end{matrix}\right)\right]$$

$$\text{or} \quad \text{(subcounty 1970 coal consumption)} \times \left[\text{subcounty correction factor for year YY}\right]$$

where CC is the coal consumption in residential furnaces and DU is the number of occupied dwelling units.

The census data on residential coal-burning furnaces are given in Table 19.

TABLE 19. NUMBER OF COAL-CONSUMING AND TOTAL HOUSING UNITS FOR THE DETROIT AREA*

	Housing Units					
	Macomb		Oakland		Wayne	
Year	Coal-Consuming	Total Occupied	Coal-Consuming	Total Occupied	Coal-Consuming	Total Occupied
1950	20,755	49,935	47,890	107,835	343,100	662,555
1960	7,709	106,995	12,978	188,986	128,309	784,668
1970	1,079	171,644	1,093	264,566	25,175	830,737

* Reference 40

From the census data, the following factors were computed to account for the trend in residential coal consumption in each county:

	Macomb	Oakland	Wayne
Ratio of 1975 to 1970 county coal consumption factors	0.48	0.44	0.55
Ratio of 1955 to 1970 county coal consumption factors	12.0	24.1	8.5

In updating data for 1975 a trend factor of 0.5 was used; population shifts were not considered.

To estimate coal consumption in residential furnaces in 1955, correction factors (coal consumption trend factor X population shift factor) were computed for subcounty areas, i.e., communities within the three counties. Appendix B gives 1955 and 1970 occupied dwelling units for each community (41, 42) and lists calculated population shift and correction factors. The communities are shown in Figure 8. For determining a correction factor for each area-source grid, the grid map (Figure 7) was superimposed on the community map and appropriate correction factors were obtained. Table 20 gives coal consumption for each grid for years 1970, 1975 and 1955 along with the correction factors for computation of 1955 coal consumption.

Estimation of Emissions--

Estimates of BaP emissions from point sources for 1956-60 and 1975-76 are given in Table 21. The approach for estimation of emissions consisted of the following steps:

- Trend factors given in Table 18 were used to estimate 1956-60 process rates based on 1975-76 data.
- Uncontrolled emissions for 1956-60 and 1975-76 were calculated by using emission factors listed in Tables 11 and 12.
- Controlled emissions were computed based on control efficiencies for particle size less than 5μm given in Table 13.

As mentioned earlier, only trends for coke production and coal combustion were investigated. No adjustments were made for 1956-60 rates for incinerators and petroleum refining. However, it was assumed that no control equipment were in operation during the period 1956-60. Table C-1 in Apendix C gives detailed point-source emissions data in the AQDM-input format and includes data on stack parameters. (In Table C-1, source numbers 1 through 49 are point sources.) Emissions from smaller point sources with 1975-76 emissions of less than 0.3 kg/y were aggregated for each county and were treated as area sources. Table 22 lists emissions from these small-point sources by source type (source numbers 180 to 197 in Table C-1).

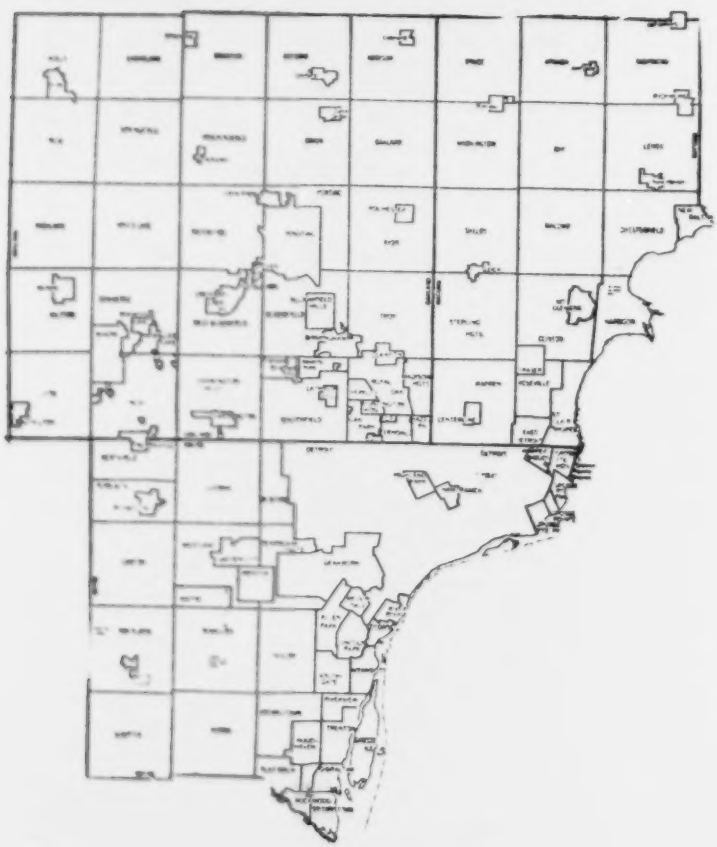

Figure 8. A Map of communities in Detroit metropolitan study area.

TABLE 20. COAL CONSUMPTION IN RESIDENTIAL FURNACES BY AREA GRIDS

Coordinates of Grid Centers, km		Correction Factor	Coal Consumption in Tons		
X	Y	for 1955	1970	1975	1955
285	4745	24.9	20	10	500
285	4735	24.0	10	5	240
285	4725	19.6	30	15	590
285	4715	23.3	20	10	470
285	4705	21.0	20	10	420
292.5	4677.5	5.9	60	30	350
292.5	4682.5	5.4	30	15	160
292.5	4687.5	3.7	20	10	70
292.5	4692.5	2.7	50	25	130
292.5	4697.5	4.0	30	15	120
292.5	4707.5	21.5	10	5	210
292.5	4712.5	20.3	10	5	200
292.5	4717.5	20.3	10	5	200
295	4670	4.9	100	50	490
295	4725	18.0	60	30	1080
295	4735	21.3	10	5	210
295	4745	19.7	10	5	200
302.5	4677.5	5.2	90	45	470
302.5	4682.5	5.5	270	135	150
302.5	4687.5	2.9	300	150	870
302.5	4692.5	3.2	250	125	800
302.5	4697.5	3.5	250	125	800
302.5	4702.5	15.3	40	20	610
302.5	4707.5	13.2	50	25	660
302.5	4717.5	21.8	30	15	650
302.5	4722.5	23.4	30	15	700
302.5	4727.5	23.4	10	5	230
305	4670	7.2	100	50	720
305	4735	21.5	70	35	1510
305	4745	29.7	20	10	590

(continued)

TABLE 20. (continued)

Coordinates of Grid Centers, km		Correction Factor	Coal Consumption in Tons		
X	Y	for 1955	1970	1975	1955
307.5	4677.5	5.2	40	20	21
307.5	4682.5	4.5	290	145	1300
307.5	4687.5	5.1	590	295	3010
307.5	4692.5	3.2	330	115	1060
307.5	4697.5	3.5	330	115	1150
307.5	4702.5	15.3	150	75	2290
307.5	4707.5	13.2	40	20	530
307.5	4712.5	13.9	30	15	420
307.5	4717.5	21.8	20	10	440
307.5	4722.5	24.4	60	30	1460
307.5	4727.5	23.4	30	15	700
312.5	4662.5	5.9	70	35	410
312.5	4667.5	5.4	50	25	270
312.5	4672.5	6.2	100	50	620
312.5	4677.5	4.9	290	145	1420
312.5	4682.5	4.9	580	290	2840
312.5	4687.5	5.8	610	305	3540
312.5	4692.5	6.8	660	330	4490
312.5	4697.5	8.4	660	330	5540
312.5	4702.5	12.9	290	145	3740
312.5	4707.5	13.4	40	20	540
312.5	4712.5	11.6	40	20	460
312.5	4717.5	11.6	30	15	350
312.5	4922.5	36.4	150	75	5500
312.5	4727.5	31.3	70	35	2190
315	4735	18.7	60	30	1120
315	4745	17.7	20	10	350
317.5	4662.5	4.9	40	20	200
317.5	4667.5	5.2	190	95	990

(continued)

TABLE 20. (continued)

Coordinates of Grid Centers, km		Correction Factor for 1955	Coal Consumption in Tons		
X	Y		1970	1975	1955
317.5	4672.5	5.3	310	155	1640
317.5	4677.5	6.0	630	315	3800
317.5	4682.5	7.8	520	260	4060
317.5	4687.5	9.0	410	205	3690
317.5	4692.5	10.0	1110	555	11100
317.5	4697.5	10.0	1110	555	11100
317.5	4702.5	17.0	310	155	5270
317.5	4707.5	20.2	130	65	2630
317.5	4712.5	33.3	150	75	5000
317.5	4722.5	22.6	40	20	900
317.5	4727.5	22.6	10	5	230
317.5	4657.5	5.6	20	10	110
322.5	4662.5	5.6	20	10	110
322.5	4667.5	4.9	70	35	340
322.5	4672.5	6.2	250	125	1550
322.5	4677.5	8.0	570	285	4560
322.5	4682.5	9.1	610	305	5550
322.5	4687.5	9.4	800	400	7520
322.5	4692.5	10.0	1330	665	13300
322.5	4697.5	10.0	1130	565	11300
322.5	4702.5	32.5	400	200	13000
322.5	4707.5	39.8	290	145	11540
322.5	4712.5	19.9	90	45	1790
322.5	4717.5	13.5	10	5	140
322.5	4722.5	19.8	20	10	400
322.5	4727.5	21.7	40	20	870
325	4735	17.5	30	15	520
325	4745	23.8	10	5	240
327.5	4682.5	10.0	70	35	700

(continued)

TABLE 20. (continued)

Coordinates of Grid Centers, km		Correction Factor	Coal Consumption in Tons		
X	Y	for 1955	1970	1975	1955
327.5	4687.5	10.0	1080	540	10800
327.5	4692.5	10.0	2170	1085	21700
327.5	4697.5	10.4	1350	675	14040
327.5	4702.5	37.8	410	205	15500
327.5	4707.5	19.4	180	90	3490
327.5	4712.5	13.5	50	25	680
327.5	4717.5	13.5	10	5	130
327.5	4722.5	20.1	10	5	200
327.5	4727.5	22.8	20	10	460
332.5	4687.5	10.0	700	350	700
332.5	4692.5	10.0	1360	680	13600
332.5	4697.5	10.5	1010	505	10600
332.5	4702.5	14.0	350	175	4900
332.5	4707.5	14.0	110	55	1540
332.5	4712.5	4.6	40	20	180
332.5	4717.5	3.6	60	30	220
332.5	4722.5	10.2	20	10	200
332.5	4727.5	9.7	20	10	190
335	4735	11.2	20	10	220
335	4745	15.4	20	10	310
337.5	4692.5	10.0	930	465	9300
337.5	4697.5	10.0	310	155	3100
337.5	4702.5	13.9	360	180	5000
337.5	4707.5	10.8	140	70	1510
337.5	4712.5	4.6	60	30	280
337.5	4717.5	5.9	20	10	120
340	4725	13.0	20	10	260
342.5	4692.5	8.4	340	170	2860

(continued)

TABLE 20. (continued)

Coordinates of Grid Centers, km		Correction Factor for 1955	Coal Consumption in Tons		
X	Y		1970	1975	1955
342.5	4697.5	8.1	800	400	6480
342.5	4702.5	16.8	320	160	5380
342.5	4707.5	15.2	200	100	3040
342.5	4712.5	6.4	80	40	510
342.5	4717.5	9.7	30	15	290
345	4735	18.8	10	5	190
347.5	4702.5	14.6	30	15	440
347.5	4707.5	14.6	20	10	290
347.5	4712.5	11.1	60	30	670
347.5	4717.5	16.9	80	40	1350
350	4725	14.6	20	10	290
352.5	4717.5	10.6	20	10	210
355	4735	19.2	20	10	380
355	4745	21.7	10	5	220

TABLE 21. BaP EMISSION ESTIMATES FOR POINT SOURCES

Type of Source (Equipment #)*	Establishment Number	Emission Factor (g/ton)	Process Rate 1956-60	Process Rate 1975-76	Uncontrolled Emissions (g/yr) 1956-60	Uncontrolled Emissions (g/yr) 1975-76	1975 Control Equipment* 1	2	3	Control Efficiencies, %(All Sizes) 1	2	3	Control Efficiencies, %(< 5μm) 1	2	3	Emissions (kg/yr) 1956-60	Emissions (kg/yr) 1975-76
Coke Production (0700)			(Tons of Coal Charged)														
	A8640	1.4	2,126,561	1,933,237	2,977,200	2,706,000							66			2977	1013
	A9740	1.4	376,258	342,000	526,800	478,900							51			761	235
	B3638	1.4	375,272	341,157	524,900	477,181							60			524	189
	B3638	1.4	857,353	779,412	1,199,000	1,091,000							60			1199	435
	B3638	1.4	750,545	682,314	1,050,000	954,000							60			1050	382
	B3638	1.4	903,541	821,401	1,265,700	1,150,600							60			1266	458
Petroleum Refineries (0980)			(Barrels of Crude/Yr)														
	A9831	0.00024	9,473,990	9,473,990	2,274	2,274	03			74.5			25			2.3	1.7
Incinerators (0005-0008)			(Tons of Refuse Burned)														
	B3694	0.31	5,000	5,000	1,550	1,550	015	05		0	93.61		0	85		1.5	0.23
	B3695	0.31	38,928	38,928	12,067	12,067	015			0			0			12.1	12.1
	F1754 (Macomb County)	0.31	3,392	3,392	1,052	1,052	011	014		0			0			1.1	1.1
	A9800 (Oakland County)	0.31	3,462	3,462	1,073	1,073	011	014		0			0			1.1	1.1
	B4140	0.31	122,000	122,000	40,920	40,920	05	07		93.6	99.5		85	99		40.9	0.06

* See Appendix A for explanation of equipment and control equipment codes.

(continued)

TABLE 21. (continued)

Type of Source (Equipment #)*	Establishment Number	Emission Factor (g/ton)	Process Rate (tons/yr)		Uncontrolled Emissions (g/yr)		1975 Control Equipment*			Control Efficiencies, %(All Sizes)			Control Efficiencies %(< 5μm)			Emissions (kg/yr)	
			1956-60	1975-76	1956-60	1975-76	1	2	3	1	2	3	1	2	3	1956-60	1975-76
Hand-Fired Coal Boilers (0019)			(Coal Consumed Tons/Yr)														
	K5259	45	62	7	2800	315	0			0			0			2.80	0.31
	K5754	45	712	80	3200	360	0									3.20	0.36
	K7412	45	80	9	3600	405	0									3.60	0.40
	K7732	45	107	12	4800	540	0									4.80	0.54
	K7875	45	890	100	4010	450	0									4.01	0.45
	L0919	45	1744	196	7850	882	0									16.54	1.86
	L0919	45	1219	137	5482	616	0										
	L0919	45	71	8	3204	360	0										
	L0936	45	1273	143	5723	643	0									15.45	1.74
	L0936	45	1273	143	5723	643	0										
	L0936	45	89	10	4005	450	0										
	L0937	45	926	104	4165	468	0									11.93	1.34
	L0937	45	926	104	4165		0										
	L0937	45	80	9	3604	405	0										
	L0949	45	926	104	4165	468	0									13.54	1.52
	L0949	45	926	104	4165	468	0										
	L0949	45	116	13	5206	585	0										
	L0960	45	979	110	4405	495	0									4.41	0.49
	L0975	45	934	105	4201	472	0									9.41	1.06
	L0975	45	116	13	5206	585	0										
	L1078	45	107	12	4806	540	0									4.81	0.54
	L1092	45	1557	175	7004	787	0									8.21	0.92
	L1092	45	27	3	1201	135	0										

(continued)

TABLE 21. (continued)

Type of Source (Equipment #)*	Establishment Number	Emission Factor (g/ton)	Process Rate (tons/yr)		Uncontrolled Emissions (g/yr)		1975 Control Equipment*			Control Efficiencies, % (All Sizes)			Control Efficiencies, % (<5μm)			Emissions (kg/yr)	
			1956-60	1975-76	1956-60	1975-76	1	2	3	1	2	3	1	2	3	1956-60	1975-76
Hand-Fired Coal Boilers (0019)			(Coal Consumed Tons/Yr)														
	L1099	45	80	9	3600	405	0			0			0			3.60	0.40
	L1102	45	62	7	2800	315	0									2.80	0.31
	L1164	4.5	667	75	2999	337	0										
	L1164	4.5	667	75	2999	337	0									10.80	1.21
	L1164	45	107	12	4806	540	0										
	L1170	45	98	11	4405	495	0									4.41	0.49
	L1185	45	80	9	3604	405	0									3.60	0.40
	L1187	45	89	10	4005	450	0									4.01	0.45
	L1239	45	89	10	4005	450	0									4.01	0.45
	L1249	4.5	667	75	2999	337	0										
	L1249	4.5	667	75	2999	337	0									6.00	0.67
	L1250	45	71	8	3204	360	0									3.20	0.36
	L1251	4.5	703	79	2981	355	0									3.16	0.35
	L1252	4.5	1477	166	6648	747	0										
	L1252	45	80	9	3604	405	0									10.52	1.15
	L1257	45	71	8	3204	360	0									3.20	0.36
	L1259	45	107	12	4806	540	0									4.81	0.54
	L1302	45	98	11	4405	495	0									4.41	0.49
	L1417	4.5	979	110	4405	495	0									4.41	0.49
	M3257	45	89	10	4005	450	0									4.01	0.45

(continued)

TABLE 21. (continued)

Type of Source (Equipment #) a	Establishment Number	Emission Factor (g/ton)	Process Rate (tons/yr)		Uncontrolled Emissions (g/yr)		1975 Control Equipment a			Control Efficiencies, % (All Sites)			Control Efficiencies, % (<5um)			Emissions (kg/yr)	
			1956-60	1975-76	1956-60	1975-76	1	2	3	1	2	3	1	2	3	1956-60	1975-76
Coal-Fired Underfeed Stokers (0020)			(Coal Consumed Tons/Yr)														
	B4009	0.003	15,792	13,160	47	39	0			0			0			0.60	0.49
	B4009	0.003	43,524	36,270	131	109	0										
	B4009	0.003	31,044	25,870	92	77	0										
	B4009	0.003	51,048	42,540	154	154	0										
	B4009	0.003	7,080	5,900	22	18	0										
	B4009	0.003	49,440	41,200	148	123	0										
	K7723	0.14	1,660	1,383	232	193	0									3.44	0.39
	K7723	0.14	1,660	1,383	232	193	0										
Large Coal-Fired Boilers (0021-0024)	B2811	0.002	72,136	144,272	144	288	013			97			75			1.88	0.37
	B2811	0.002	72,136	144,272	144	288	013			97			75				
	B2811	0.002	72,136	144,272	144	288	013			97			75				
	B2811	0.002	72,136	144,272	144	288	013			97			75				
	B2811	0.002	652,173	1,304,346	1,304	2,608	013			99			97				
	B2185	0.012	2,063	4,127	24	49										1.20	0.36
	B2185	0.012	1,572	3,145	19	38											
	B2185	0.012	1,025	2,050	12	25											
	B2185	0.012	36,910	73,820	442	885	03	013		74.2	97			72			
	B2800	0.012	28,064	56,128	336	673	013	03		8			75			1.35	0.67
	B2800	0.012	28,064	56,128	336	673	013	03		8			75				
	B2800	0.012	28,064	56,128	336	673	013			98			75				
	B2800	0.012	28,064	56,128	336	673	013			98			75				
	B3009	0.012	33,362	66,725	400	801	013	03		97	63		72			0.80	0.45
	B3009	0.012	33,362	66,725	400	801	013	03		97	63		72				

TABLE 22. BaP EMISSION ESTIMATES FOR POINT SOURCES WITH LESS THAN 0.3 kg/yr EMISSIONS IN 1975-76

	Macomb	Oakland	Wayne	Total
1956-60 Annual Emissions				
Coal-fired boilers	4.3	3.2	74.5	82.0
Incinerators*	2.6	4.3	19.3	26.2
1975-76 Annual Emissions				
Coal-fired boilers	0.5	0.6	8.2	9.3
Incinerators	2.6	4.3	19.3	26.2

* Same as 1975-76 estimates.

Emission estimates for area sources are given in Table C-1, source numbers 50 through 179. The coal consumption figures for 1955 and 1975 given in Table 20 and emission factors listed in Table 11 were used to compute emission estimates. Stack height was assumed to be 10 m for all area sources representing residential coal combustion.

Air Quality Data

Ambient BaP concentrations in Detroit have been measured by at least four organizations or investigators over a timespan of approximately 20 years. Figure 9 shows locations of monitoring sites and indicates periods of measurements. Pre-1960 measurements are available only for one site and for 1 yr in duration (18). The NASN monitoring program for BaP which began in 1966 offers long-term trend data. However, the uninterrupted continuous data measurements in the Detroit area are also for only a single site (43, 44). In 1968, BaP measurements at several sites in the Detroit-Windsor area (three in Detroit) were performed under a United States-Canada International Joint Commission Study (45). Fairly comprehensive spatial measurements are available for Wayne County since 1971 (16).

BaP air quality data for the period 1958 through 1976 are plotted in Figure 10. Concentrations at the NASN site show a clear downward trend. Such a trend is not evident for Wayne County sites. Similarly, BaP concentrations measured at the NASN site were close to the lowest observed concentrations among the six Wayne County sites. The NASN site is between two Wayne County sites, '02' and '04', and all three lie almost on a straight line. The concentrations at Wayne County site '04' and the NASN site are plotted in Figure 11. No clear explanation for the differences between NASN and Wayne County measurements was found; techniques for laboratory analysis were basically the same for both. EPA has been using an improved method (46) since 1972; the improvements primarily relate to increases in the number of samples that can be analyzed, the specificity and sensitivity of the method, and the reproducibility of results (47). However, it was speculated that these reasons may not be sufficient to address the apparent differences in NASN and Wayne County measurements. One factor that may account for the difference is that the instruments for NASN measurements were at a height of 75 ft (22.5 m) above the ground. whereas the the Wayne County measurements were done at a standard height of 12 to 13 ft (3.6 to 3.9 m) above ground. If the combined effective height for all BaP sources was less than 75 ft (22.5 m), it is possible that the measurements at a higher elevation would be substantially less than ground measurements.

For calibration purposes, the 1975-76 air quality monitoring data for six Wayne County sites were used. The 1958-59 measurements offer only a check point in estimation of past ambient concentrations. Detailed BaP monitoring data for the Detroit area are given in Appendix D (Tables D-1 through D-4).

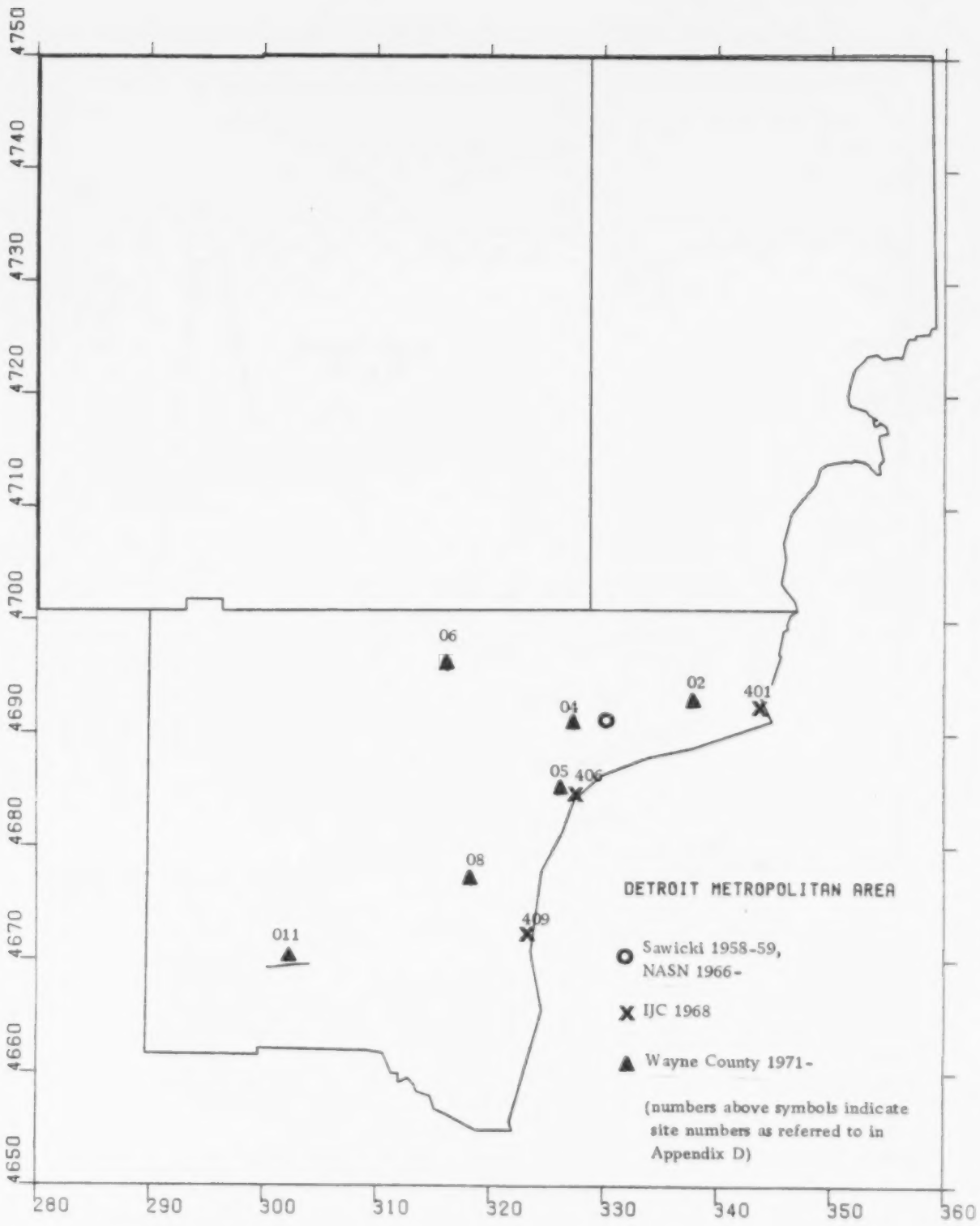

Figure 9. BaP monitoring sites.

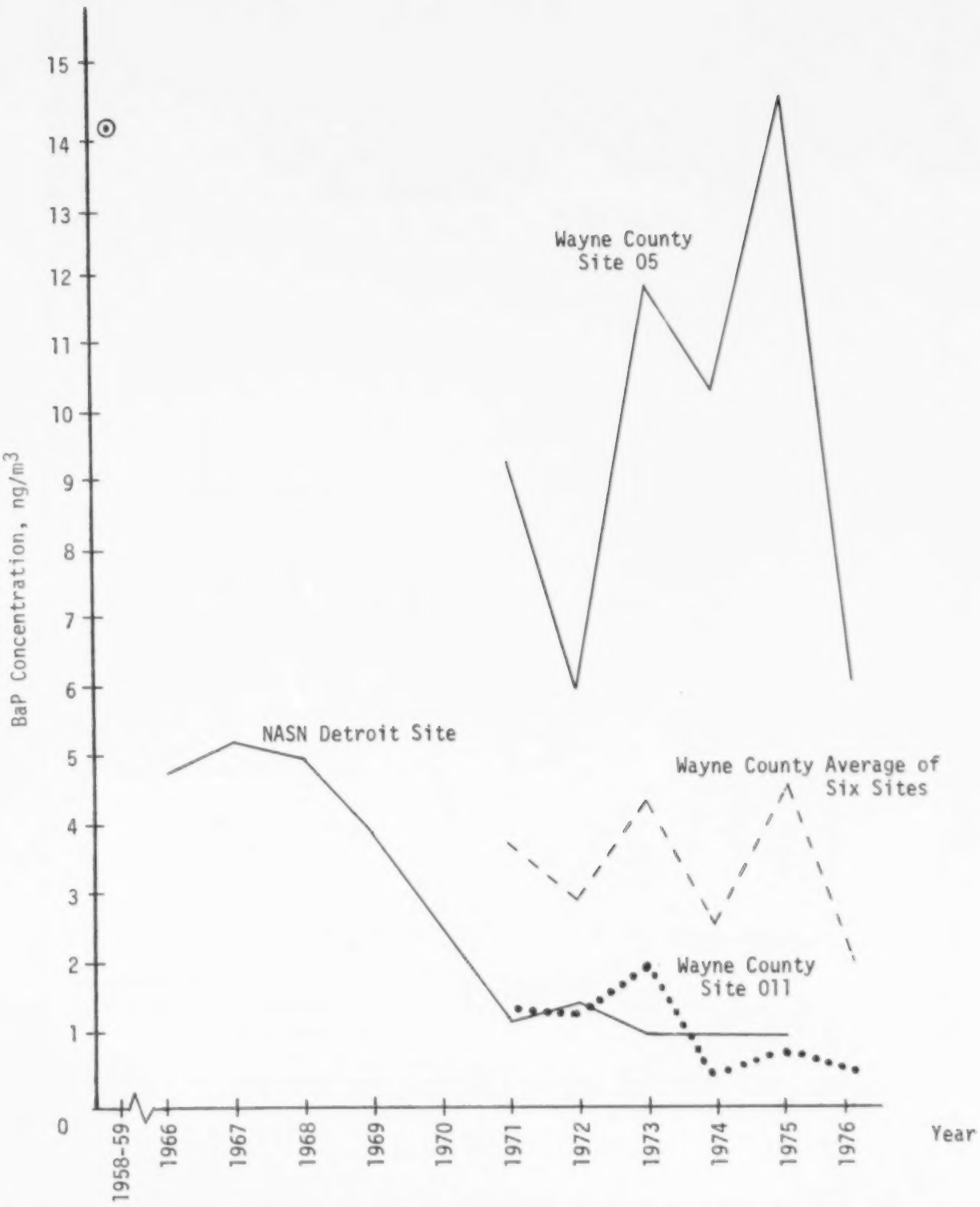

Figure 10. Reported ambient BaP concentrations in the Detroit study area, 1958-1976.

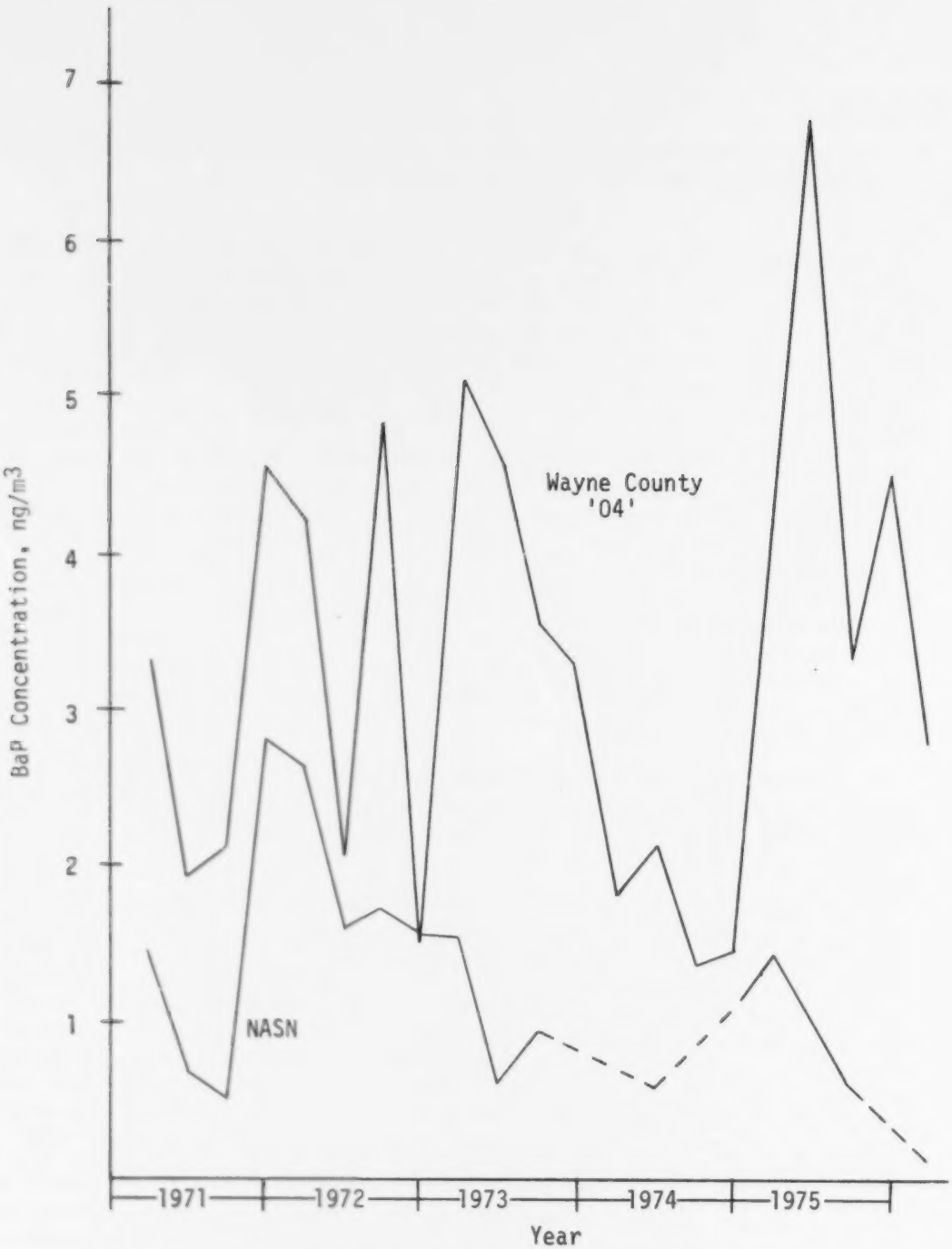

Figure 11. Quarterly BaP concentrations for the NASN site and an adjacent Wayne County site '04'.

Modeling

As mentioned previously, AQDM was used in modeling of ambient BaP concentrations for present and past conditions.

1975-76--

Emissions data for 1975-76 given in Appendix C were used. The BaP sources and strength of their emissions are depicted in Figure 12. The 1975 and 1976 meteorological data for Detroit Metropolitan Airport were converted into STAR frequency distributions for each year. An average of these two distributions was used since part of the emissions data was for 1975 and others were for 1976 (Table E-1 in Appendix E). One hundred and eighty-two grid receptors were used and, in addition, concentrations were also predicted for the six Wayne County monitoring sites. The observed versus predicted concentrations for these monitoring sites are shown in Figure 13. The agreement between the observed and predicted was excellent; 98 percent of the variation in the observed values was accounted for ($R^2 = 0.98$). The least-square regression line is shown in Figure 13, but it was not used for calibration. The regression line was such that it tended to reduce the differential between low and high concentrations. Two separate regression lines, one for low concentrations or for concentrations below approximately 2 ng/m^3 and the other for larger concentrations, may have reduced the problem but the total number of points was judged to be too small for such analysis. Instead, no calibration line was used in estimating past exposures.

Isopleths for 1975-76 BaP concentrations are shown in Figure 14. Note that even without any calibration, the observed concentrations at the monitoring sites are consistent with the predicted isopleths.

1956-60--

The BaP emission sources for 1956-60 and their relative emission rates are shown in Figure 15. (See Appendix C for detailed data.) Averaged annual meteorological frequency distributions for the period 1956 through 1960 were used (Appendix E, Table E-2). The AQDM-predicted concentrations and isopleths are shown in Figure 16. It was indicated earlier in this section that emissions from mobile sources were insignificant compared to area emissions from coal-fired residential furnaces and thus were not included in simulating 1975-76 conditions. However, it is possible that in 1956-60, due to higher emissions from older cars, automobile BaP emissions might have had a significant impact. The traffic data for 1956-60 were not available in a format from which emissions could be computed. A precaution was taken to ascertain that the low-concentration areas predicted by the model were not erroneously labeled as low due to exclusion of automobile emissions. A traffic density map for that period was superimposed onto the predicted BaP concentration map (Figure 16); areas with low BaP concentrations, but with high vehicular travel density, were excluded from "low" concentration areas. Resultant high and low exposure areas are shown in Figure 17.

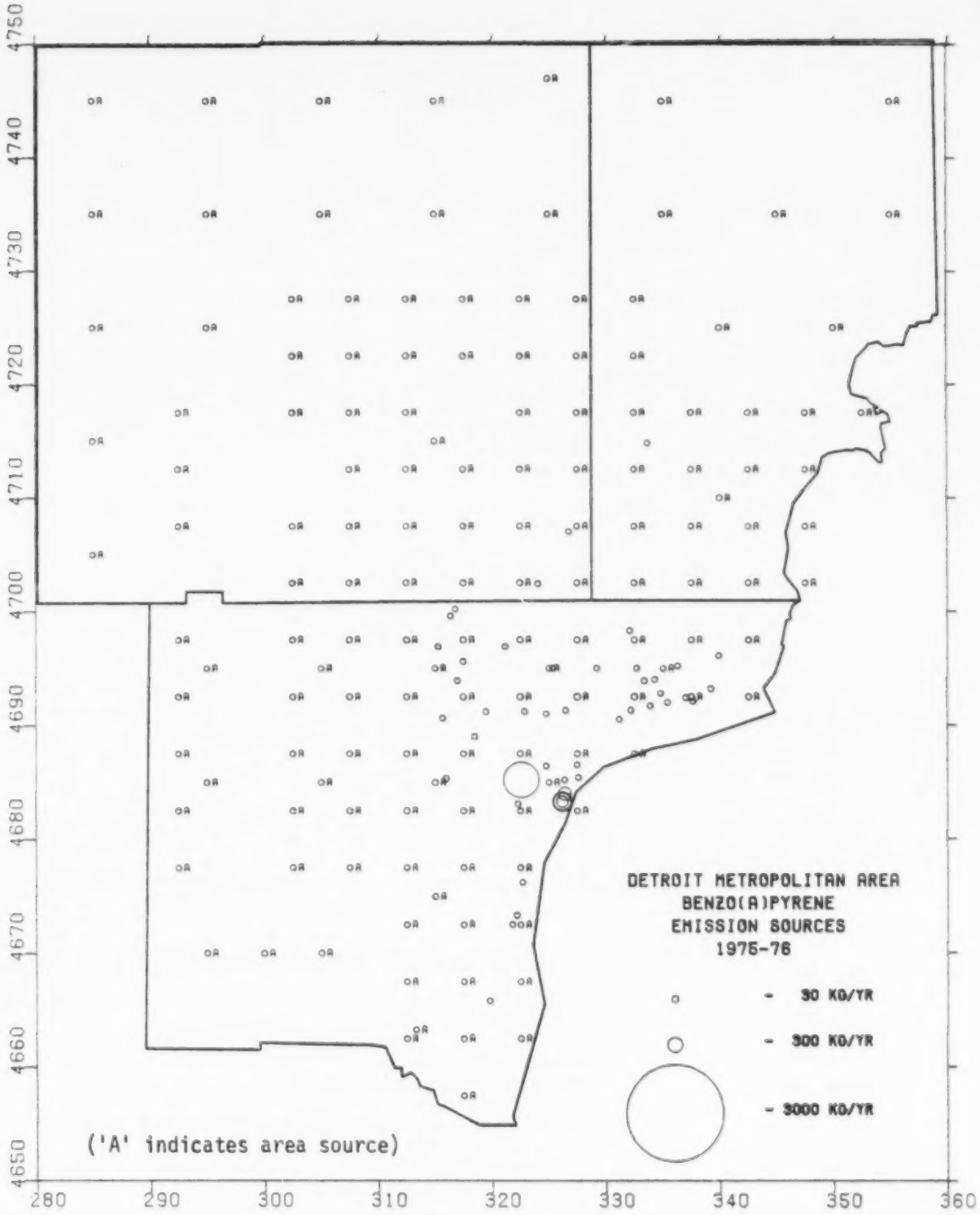

Figure 12. 1975-76 BaP sources and their emissions.

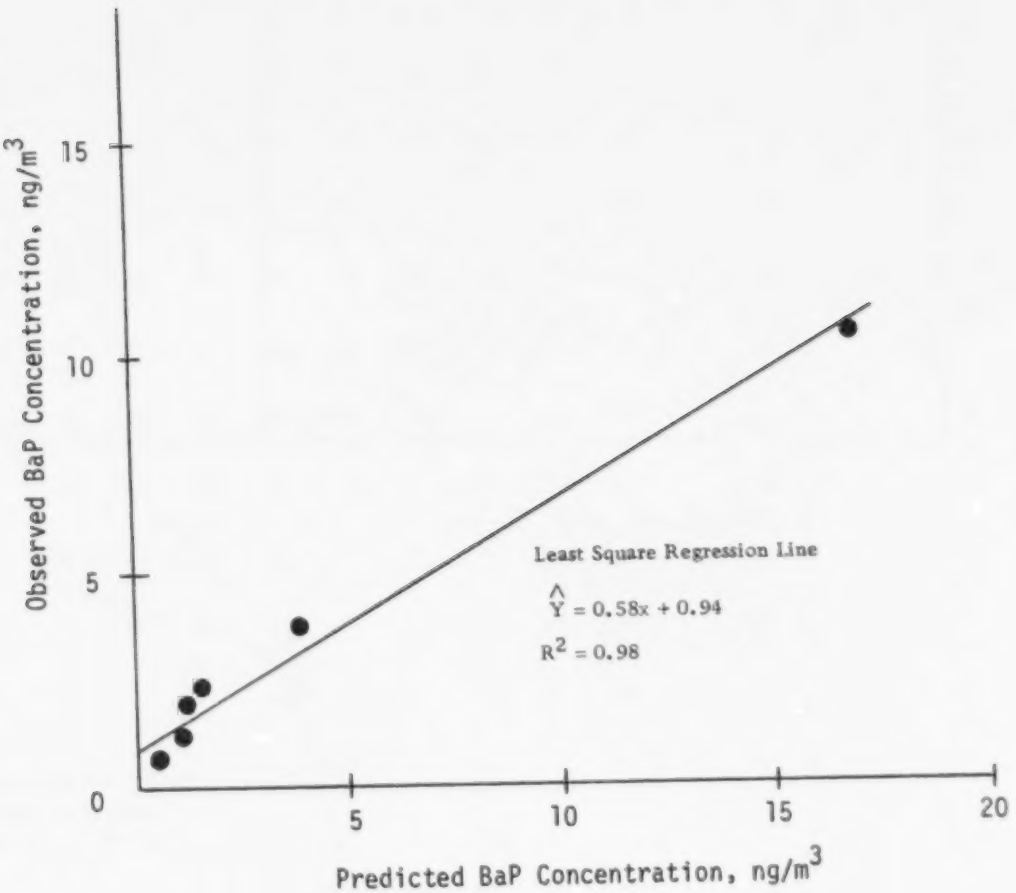

Figure 13. Observed versus AQDM predicted BaP concentrations for six Wayne County monitoring sites.

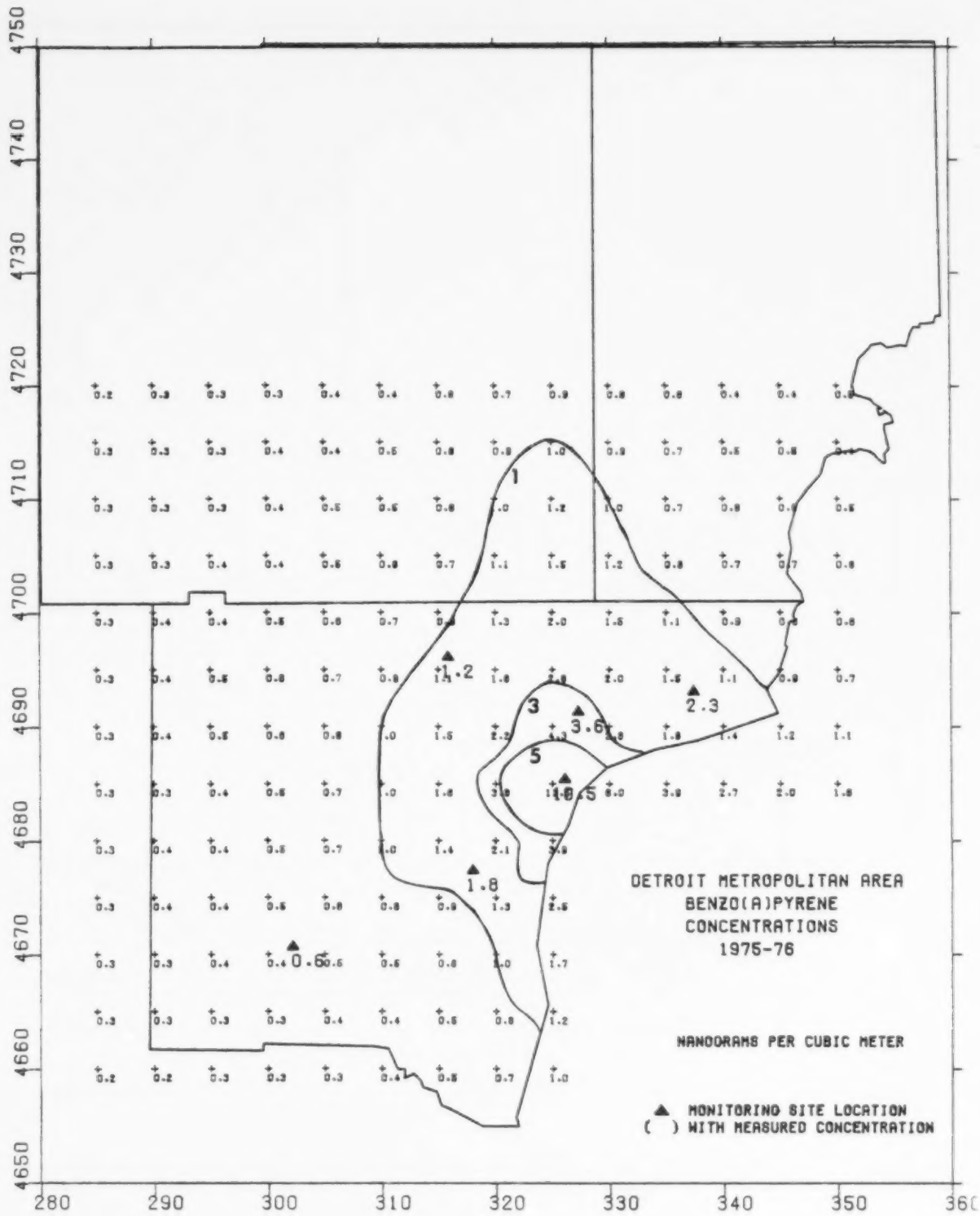

Figure 14. Predicted and observed 1975-76 ambient BaP concentrations.

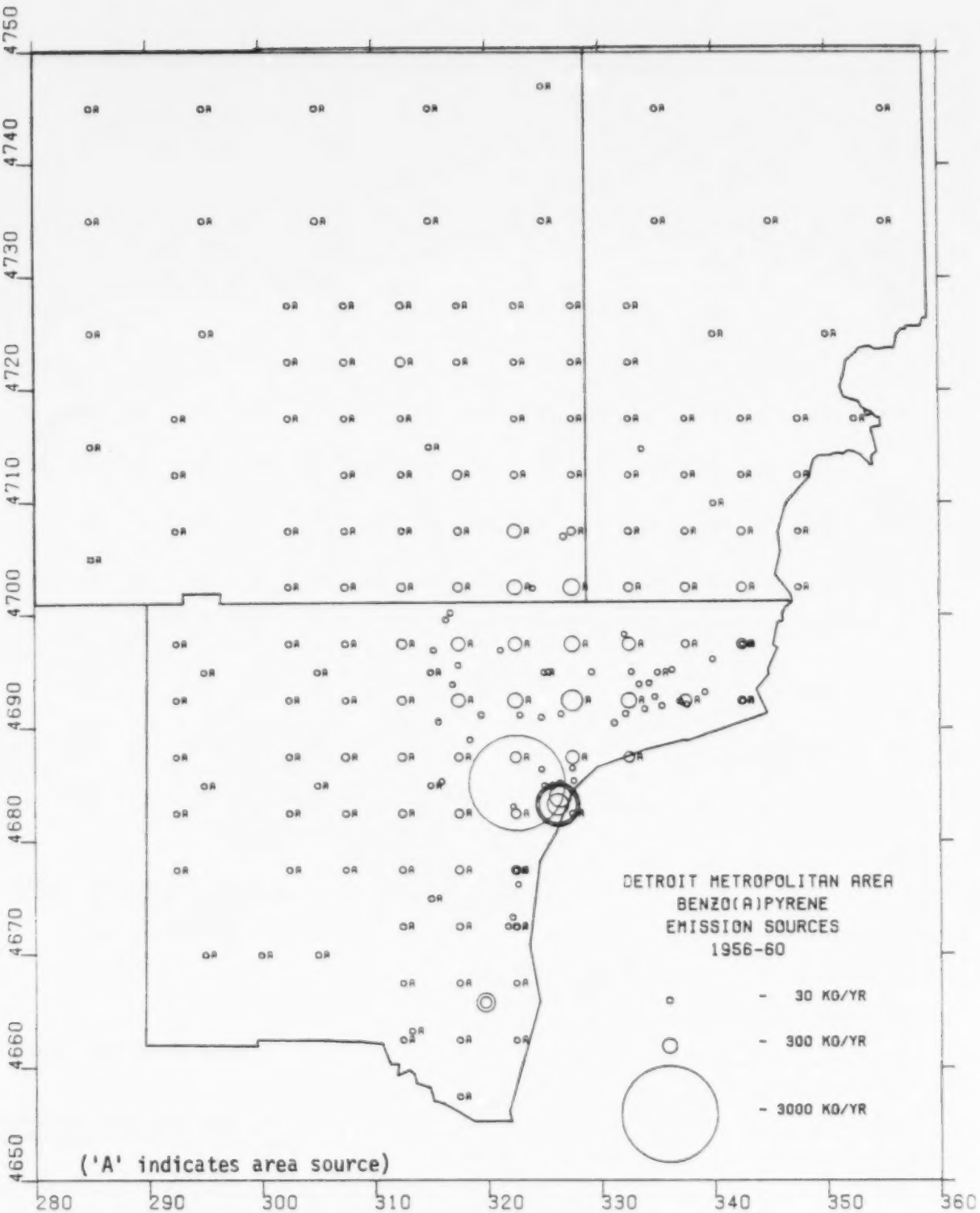

Figure 15. 1956-60 BaP sources and their emissions.

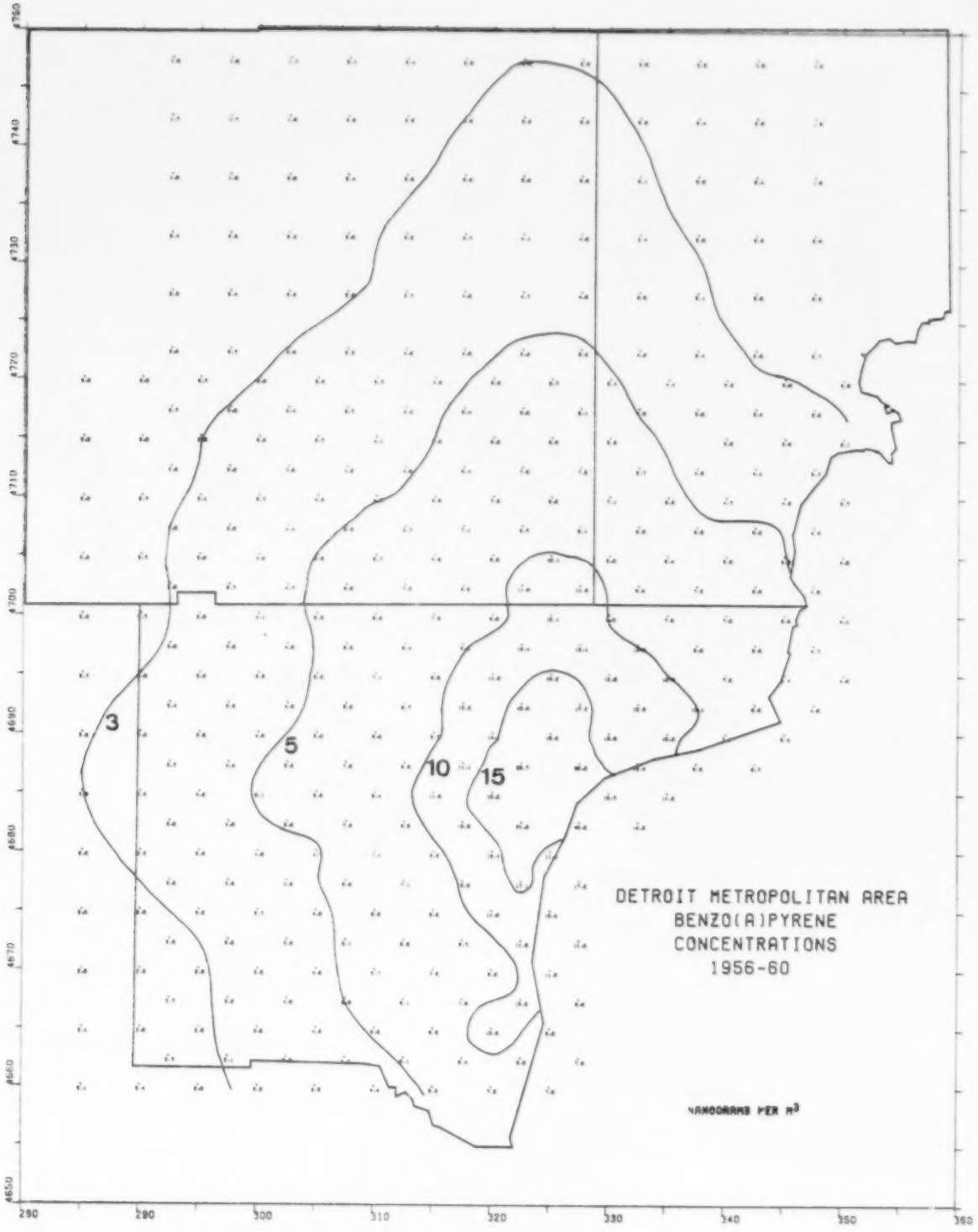

Figure 16. Predicted 1956-60 ambient BaP concentrations.

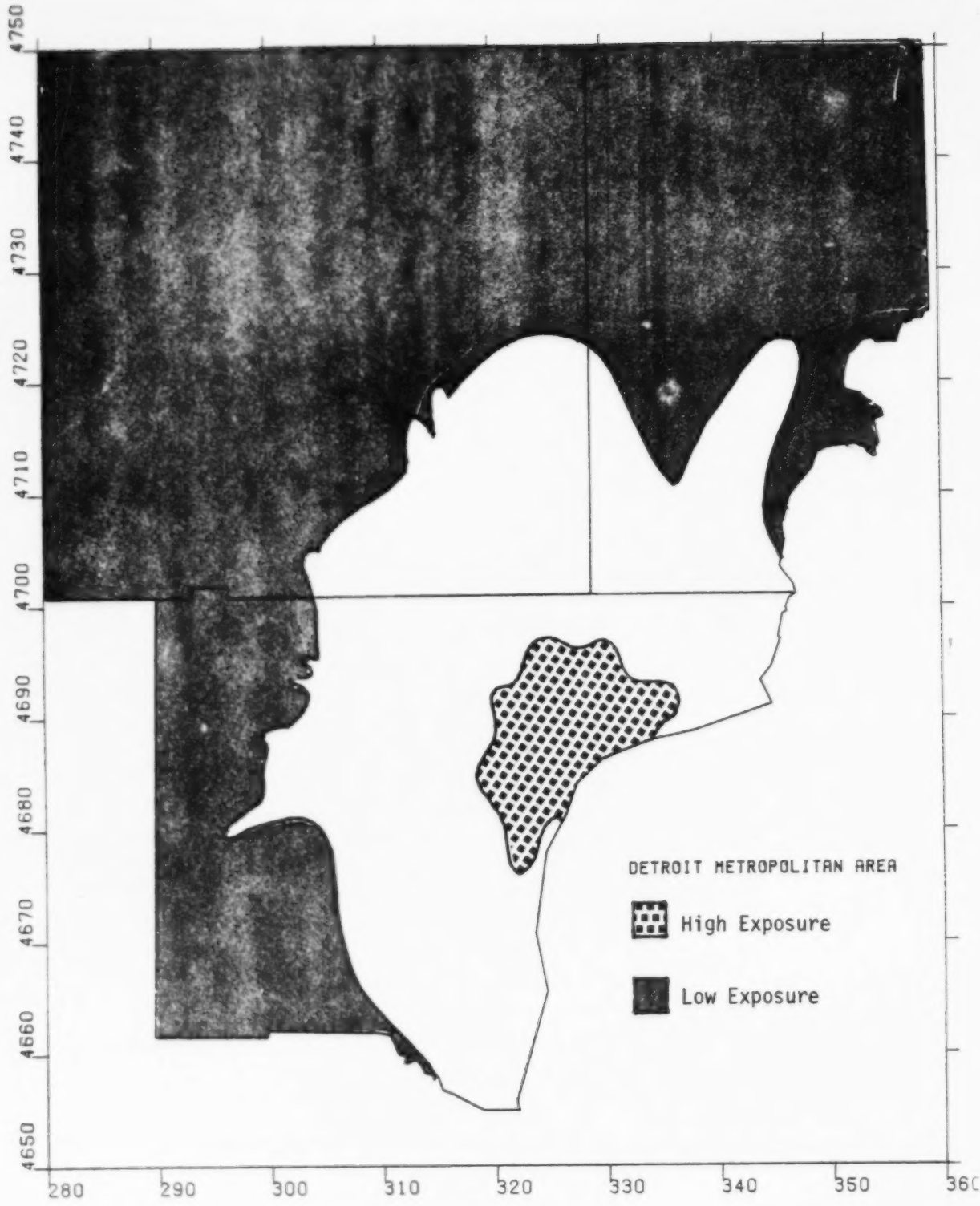

Figure 17. Characterization of ambient exposure to BaP, 1956-60.

As mentioned before, no spatial air quality data were available for the period for which BaP concentrations were predicted. Consequently, no spatial analysis was possible. However, for the single site for which 12-mo BaP measurements were available, the agreement between observed and predicted was good (observed, 15.0 ng/m^3; predicted, 14.1 ng/m^3).

In order to evaluate the importance of the sources to BaP concentration, the source contributions were analyzed for five sites. Sites were chosen so that different source-impact areas were represented (Figure 18). The source contributions by major categories are presented for these receptor sites in Table 23. As expected, coke ovens contributed significantly (over 25 percent in all cases) and the heaviest contribution is to the site nearest to coke ovens. Area sources representing coal-fired residential furnaces were also judged equally important; and for sites away from coke ovens, they were dominant. Other point sources including industrial and commercial boilers, incinerators and petroleum refining contributed generally less than 10 percent.

TRICHLOROETHYLENE

Trichloroethylene is widely used as a vapor degreasing solvent for fabricated metal parts, and this process results in substantial atmospheric emissions. Although it has not been associated with cancer in humans, recent positive tests on animals have caused increasing concern about this chemical. Unlike NEDS, Michigan's point-source data system includes a separate category for trichloroethylene under "organic solvent use" (equipment code 0031 in Appendix A). Amount of solvent usage per year was included in the data, but no emission factors were available. It was assumed that all trichloroethylene was released into the atmosphere. (About 95 percent is believed normal.) Another category which provided information on trichloroethylene emissions was metal cleaning operations (equipment code 0065). In this case, the amount of trichloroethylene makeup solvent was used as an estimate of emissions. Although there may have been some overestimation of emissions, this was not expected to have any significant impact on demarcation of high and low exposure areas. Emission sources and their relative strength are shown in Figure 19.

No data on stack parameters were available for trichloroethylene sources. This fact combined with uncertainty in the atmospheric reactivity of trichloroethylene and lack of air quality data precluded air quality modeling. Instead, the emissions data were used to compute emission densities (Figure 20) and high/low exposure areas (Figure 21).

NICKEL

Nickel and/or nickel compounds (primarily nickel subsulfide, nickel oxide, and nickel carbonyl) are believed by many researchers to be responsible for human lung and nasal cancer. As in the case of most metals, emission and air quality information on nickel compounds is generaly in terms of elemental nickel rather than specific compounds. Although nickel compounds are implied in the following discussion, it refers to nickel only.

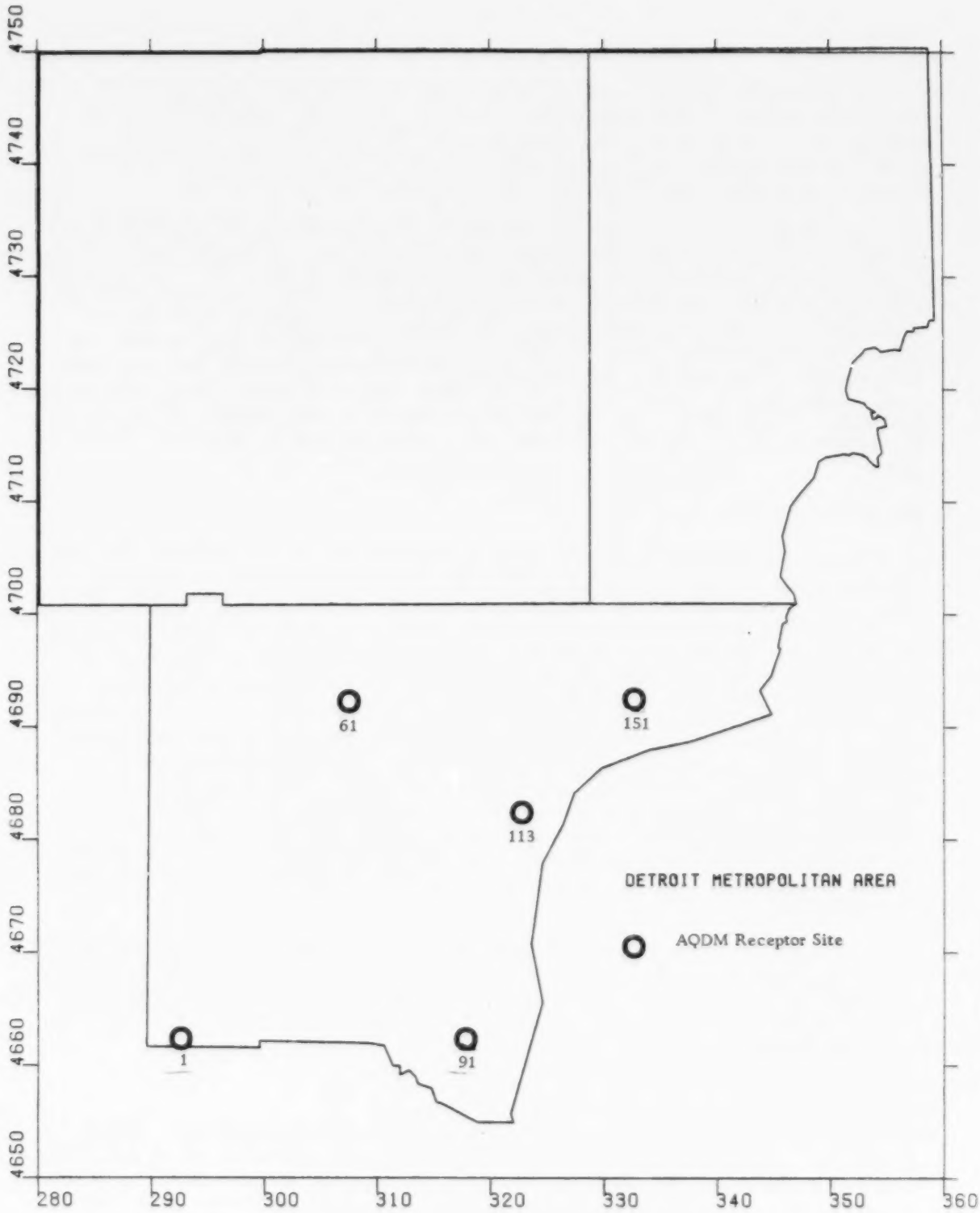

Figure 18. Receptor sites for BaP source-contribution analysis.

TABLE 23. ESTIMATED 1956-60 SOURCE CONTRIBUTIONS AT VARIOUS RECEPTOR SITES*

	Source Contribution, Percent				
Source-Category	Receptor #1	Receptor #61	Receptor #91	Receptor #113	Receptor #151
Point sources					
Coke ovens	37	26	37	78	37
Other point sources	7	4	14	2	7
Area sources					
Residential coal-fired furnaces	56	70	49	21	56
Total	100	100	100	100	100
BaP concentrations, ng/m^3	2.7	6.0	6.4	31.9	12.9

* See Figure 18.

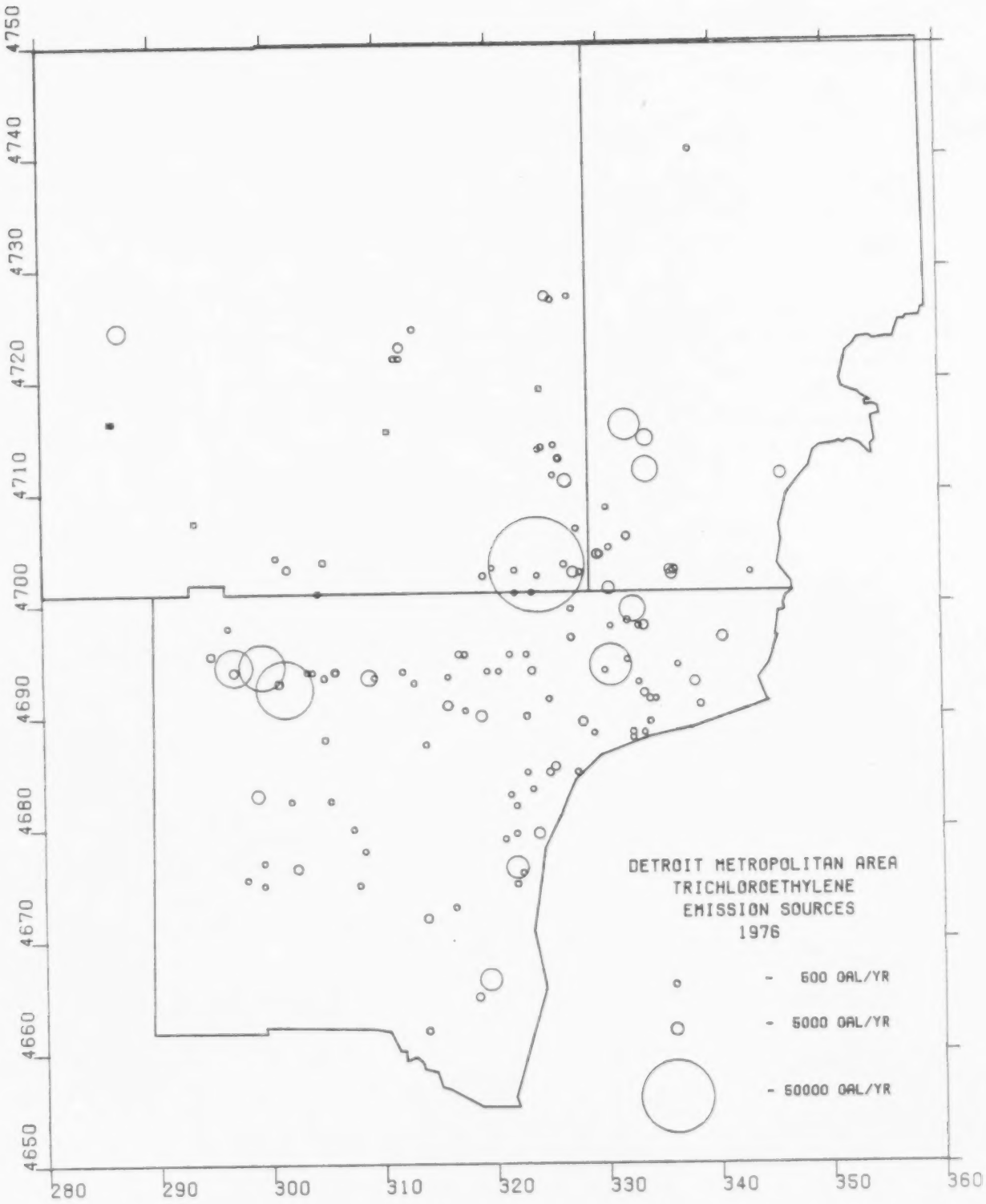

Figure 19. Sources of trichloroethylene and their emissions, 1976.

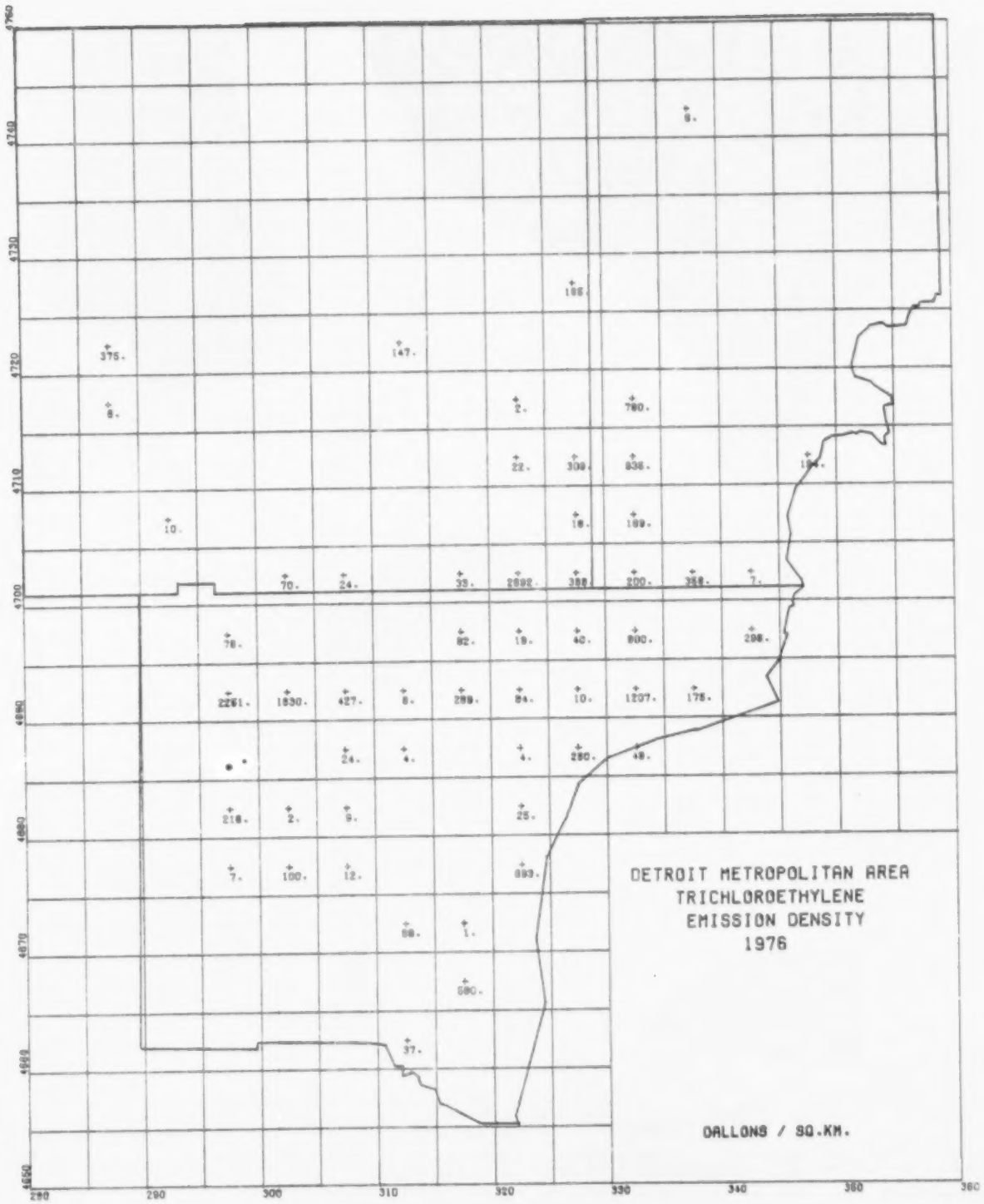

Figure 20. Trichloroethylene emission density, 1976.

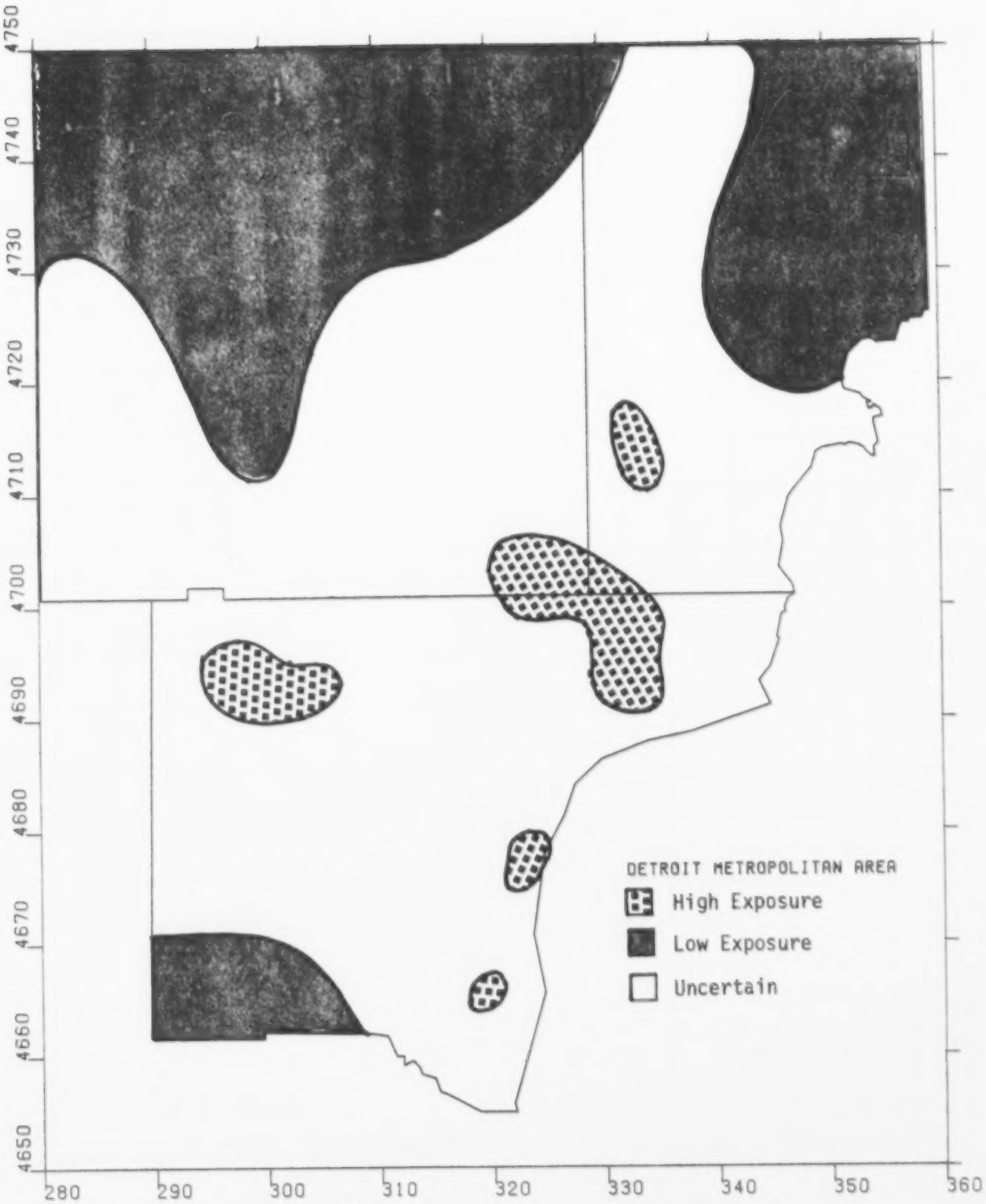

Figure 21. Characterization of ambient exposure to trichloroethylene.

Coal and oil combustion, cement manufacturing, steel production and waste incineration are major sources of nickel. Area sources for combustion could also be important; but due to limited time available, only point sources were considered in this exposure analysis. The MDNR equipment codes considered for estimation of emissions along with appropriate emission factors selected from Anderson (48) are given in Table 24. In some cases, emission factors were corrected with control efficiencies to compute the uncontrolled emissions. The quantities of material processed at each establishment were obtained from the MDNR Point Sources Data System and multiplied by the appropriate emission factors to calculate the annual uncontrolled emissions. Controlled emissions were then determined using the control efficiencies given in Table 25. Emissions data are given in Appendix C, Table C-2; emissions sources and their relative strengths are shown in Figure 22; emission density profiles are shown in Figure 23.

In order to compare emission profiles with observed air quality, ambient nickel concentration measurements at seven sampling sites were obtained from the Wayne County Air Pollution Division. Data for NASN sites were obtained but were not used in this analysis, due to incomplete or missing data (detailed air quality data are listed in Appendix D). The values at the sites with highest and lowest annual concentration during 1971 to 1976, along with the average concentrations for each year, are shown in Figure 24. The ambient nickel concentration data for 1976 were used to see the spatial variations in ambient levels of nickel (Figure 25). Although it is recognized that the isopleths in Figure 25 are based on very limited air quality data, the general distribution of ambient nickel compares extremely well with the estimated distribution of nickel emissions (Figure 23). This is remarkable since the spatial patterns of emissions and air quality were obtained from two separate independent sources of information. Figures 23 and 25 were combined to depict high and low exposure areas for nickel (Figure 26).

CADMIUM

Cadmium and several cadmium compounds have given positive results when tested for carcinogenicity in animals, with most attention centering on the lung and the prostate and testes. Some researchers have suggested cadmium as a human carcinogen, but so far no conclusive evidence of this has been presented; however, the animal evidence is believed to warrant concern about this chemical.

Atmospheric cadmium emissions in the Detroit area are primarily from point sources, the most important being zinc smelting and large-scale coal combustion. The MDNR equipment codes included for estimation of emissions along with emission factors are given in Table 26. Figure 27 shows point sources of cadmium and the relative magnitude of their emissions; detailed emission estimates are included in Appendix C. Based on the estimates of cadmium emissions, emission densities were computed (Figure 28).

TABLE 24. SOURCES OF NICKEL EMISSIONS AND THEIR EMISSION FACTORS

Process	MDNR Equipment Code	Emission factor for uncontrolled emission *
Sewage sludge incinerators		
Municipal hearth	0012	0.15 lb/ton of waste incinerated
Fluidized bed	0013	0.15 lb/ton of waste incinerated
Cement manufacturing		
Dry process kiln (gas fired)	0360	99.7 $lb/10^3$ tons of fuel
Dry process kiln (oil fired)	0361	99.7 $lbs/10^3$ tons of fuel
Dry process kiln (coal fired)	0362	99.7 $lb/10^3$ tons of fuel
Dry process mill	0365	0.2 $lb/10^3$ tons of fuel
Wet process kiln (gas fired)	0366	99.7 $lb/10^3$ tons of fuel
Wet process kiln (oil fired)	0367	99.7 $lb/10^3$ tons of fuel
Wet process kiln (coal fired)	0368	99.7 $lb/10^3$ tons of fuel
Wet process mill	0371	1.33 $lb/10^3$ tons of fuel
Alloy of steel melting -- electric arc furnace	0637	10 lb/ton Ni changed
Combustion		
Coal		19.4 $lb/10^3$ tons coal burned
Distillate oil		0.0005 $lb/10^3$ gallons oil burned
Residual oil		0.08 $lb/10^3$ gallons oil burned

* In cases where emission factors were given based on controlled emissions (48), these were corrected by the expression:

$$\text{Uncontrolled emission factor} = \frac{\text{Controlled emission factor}}{1 - \text{fractional efficiency}}$$

TABLE 25. EMISSION CONTROL EQUIPMENT AND THEIR CONTROL EFFICIENCIES

MDNR Code	Control equipment	Efficiency used, percent
01	settling chamber	59
02	single cyclone	65
03	multicyclone	80
04	other centrifugal type cyclone	91
05	scrubber with water	96
06	scrubber with solution	96
07	venturic scrubber	99.5
08	oil filter	80*
09	condenser	90*
10	fabric filter	99.7
11	after burner	80*
12	catalytic burner	95*
13	electrostatic precipitator	97
14	primary burner	60*
15	wet baffle	59

* No data, efficiencies assumed arbitrarily.

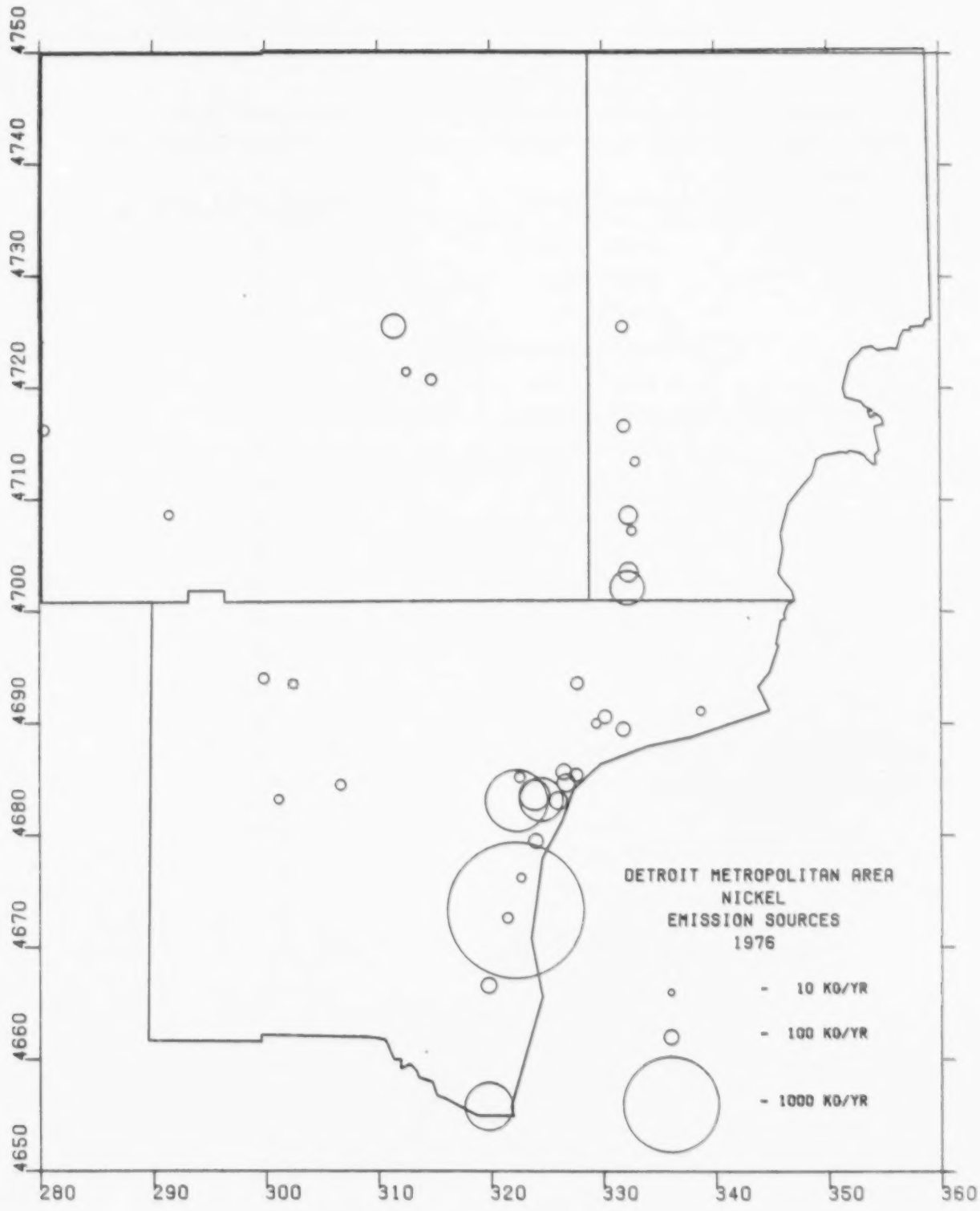

Figure 22. Sources of nickel and their emissions, 1976.

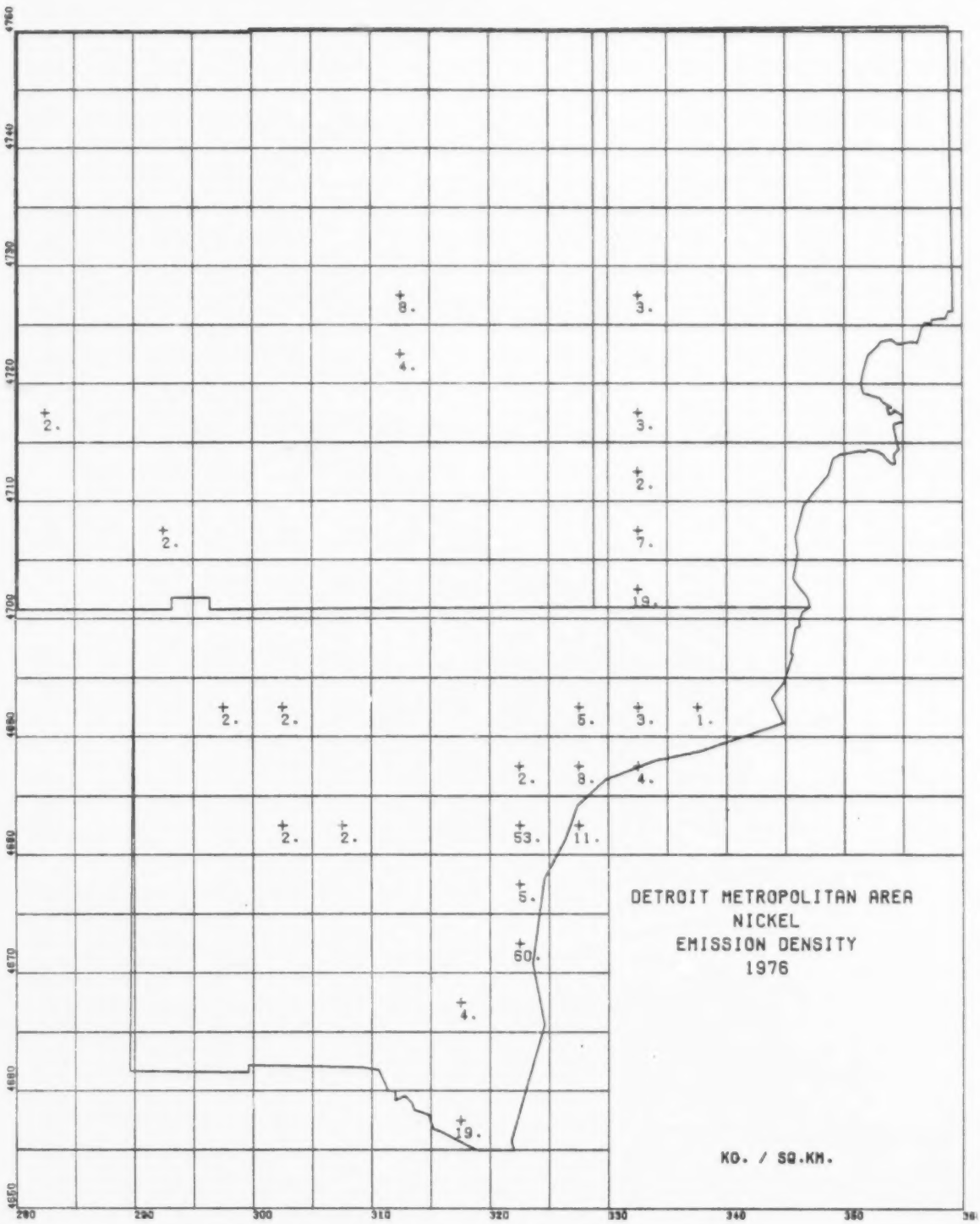

Figure 23. Nickel emission density, 1976.

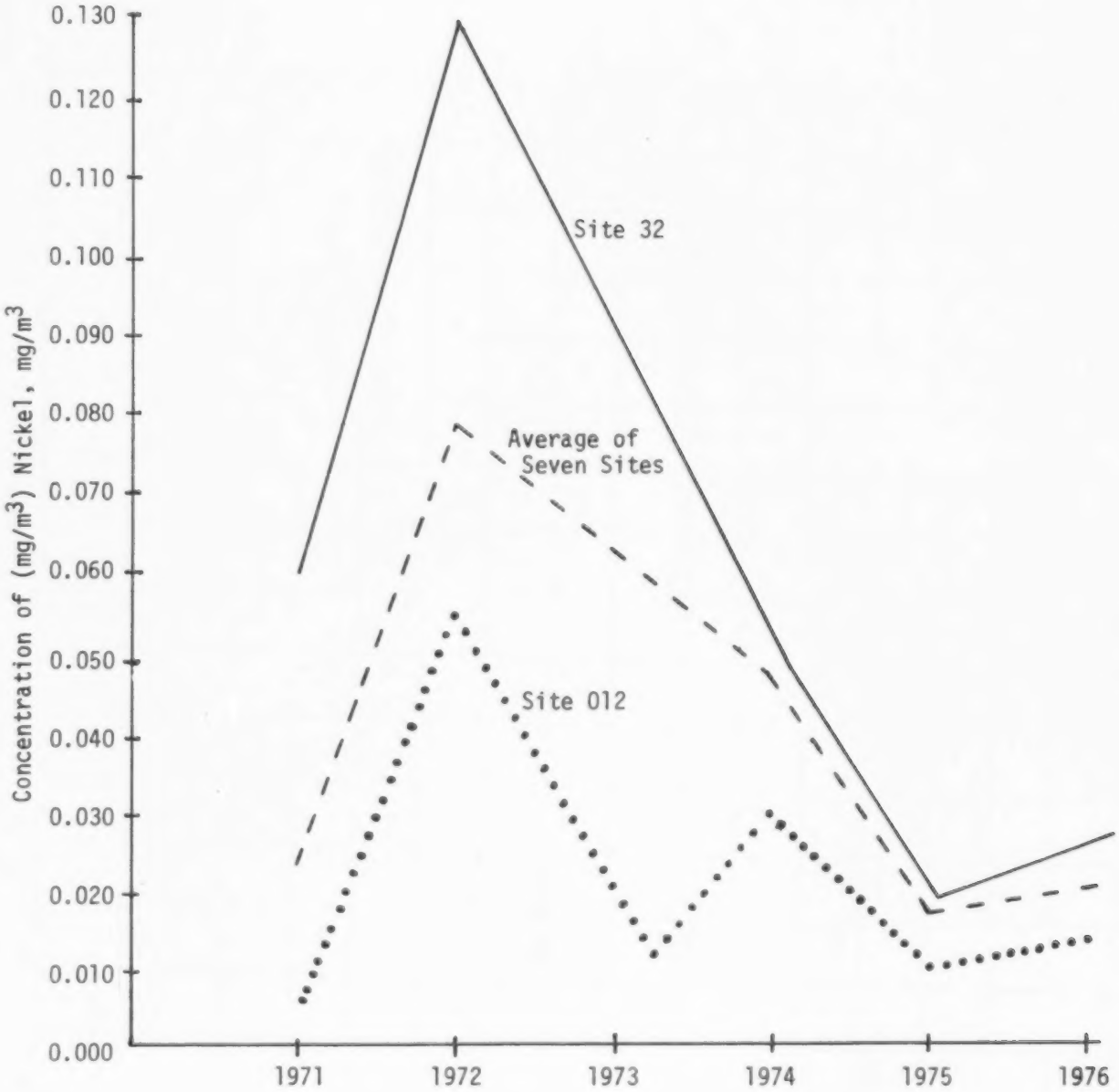

Figure 24. Ambient nickel concentrations in the Detroit metropolitan study area, 1971-76.

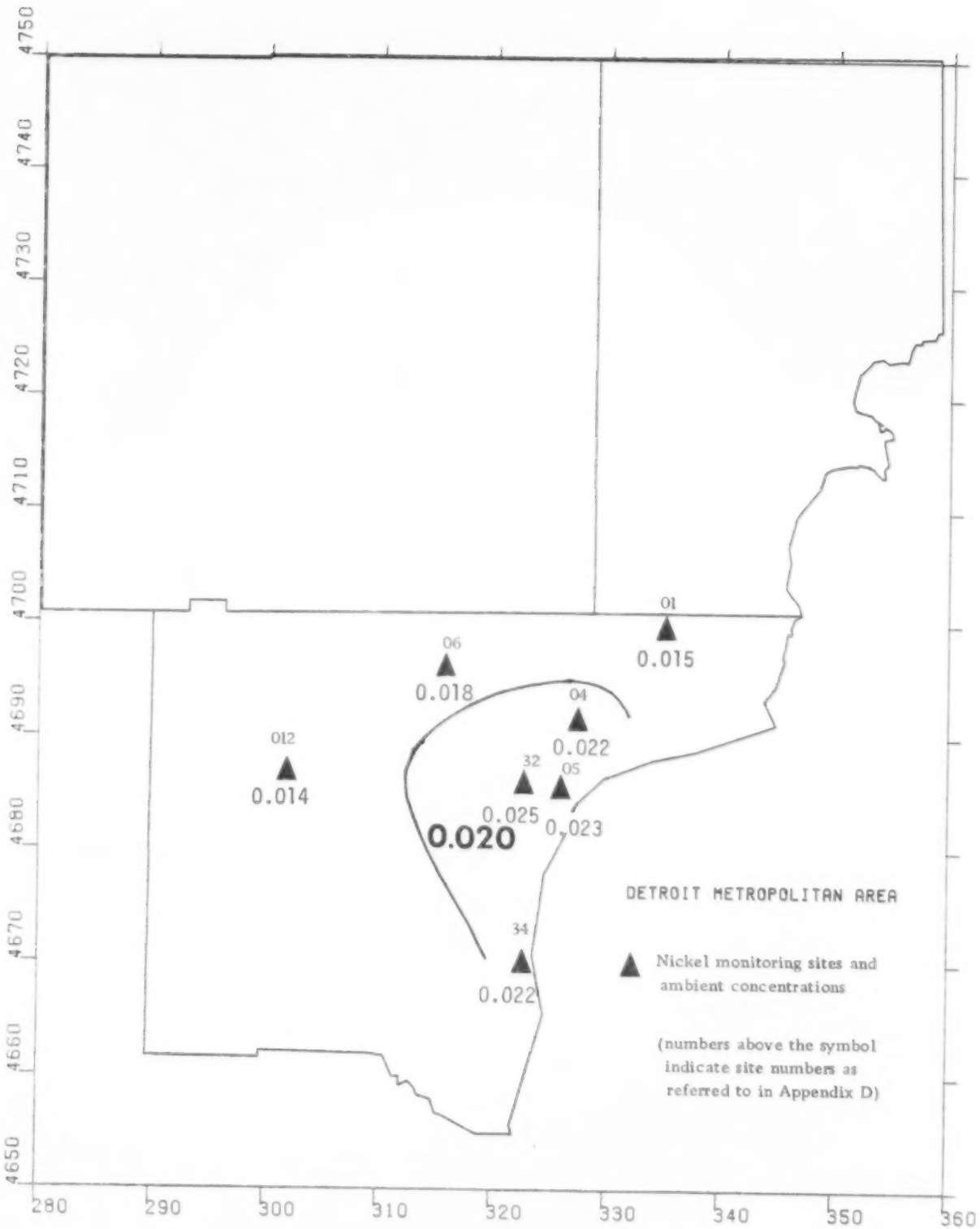

Figure 25. Ambient concentrations of nickel, 1976.

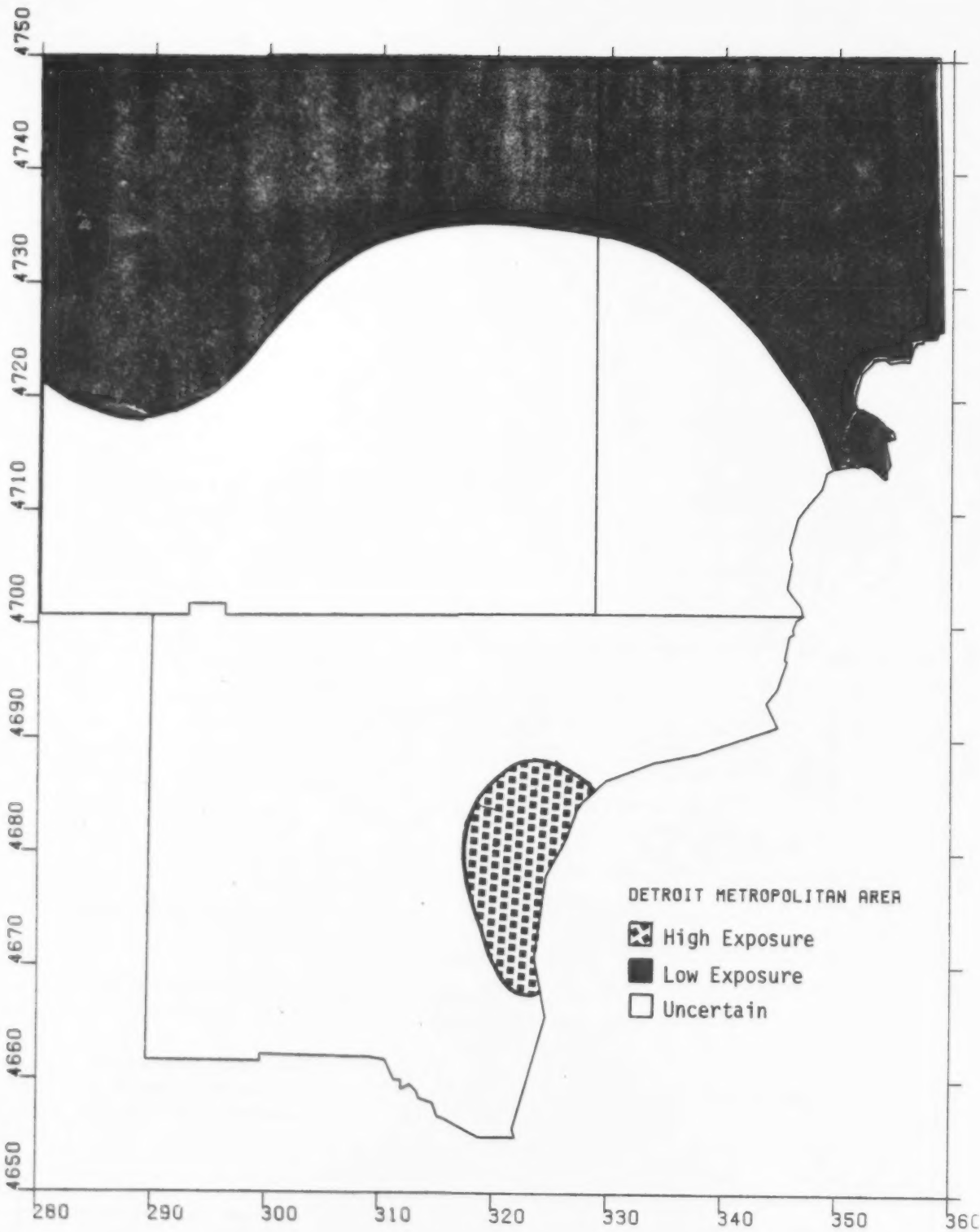

Figure 26. Characterization of ambient exposure to nickel.

TABLE 26. SOURCES OF CADMIUM EMISSIONS AND THEIR EMISSION FACTORS

Process	MDNR Equipment Code	Emission factor for uncontrolled emission *
Sewage sludge incinerators		
Municipal hearth	0012	0.34 lb/ton of waste incinerated
Fluidized bed	0013	0.34 lb/ton of waste incinerated
Cement manufacturing		
Dry process kiln (gas fired)	0360	99.7 lb/10^3 tons of fuel
Dry process kiln (oil fired)	0361	99.7 lb/10^3 tons of fuel
Dry process kiln (coal fired)	0362	99.7 lb/10^3 tons of fuel
Dry process mill	0365	99.7 lb/10^3 tons of fuel
Wet process kiln (gas fired)	0366	99.7 lb/10^3 tons of fuel
Wet process kiln (oil fired)	0367	99.7 lb/10^3 tons of fuel
Wet process kiln (coal fired)	0368	99.7 lb/10^3 tons of fuel
Wet process mill	0371	6.65 lb/10^3 tons of fuel
Lead smelting		
Reverbratory furnace	0641	0.2 lb/ton lead produced
Zinc smelting		
Retort furnace	0661	2 lb/tons of zinc produced
Horizontal muffle furnace	0662	2 lb/tons of zinc produced
Pot furnace	0663	2 lb/tons of zinc produced
Sweating furnace	0664	2 lb/tons of zinc produced
Copper smelting		
Furnace	0761	0.07 lb/ton of copper produced
Combustion		
Coal		19.4 lb/10^3 tons coal burned
Distillate oil		0.0005 lb/10^3 gallons oil burned
Residual oil		0.08 lb/10^3 gallons oil burned

* In cases where emission factors were given based on controlled emission (48), these were corrected by the expression:

$$\text{uncontrolled emission factor} = \frac{\text{controlled emission factor}}{1 - \text{fractional efficiency}}$$

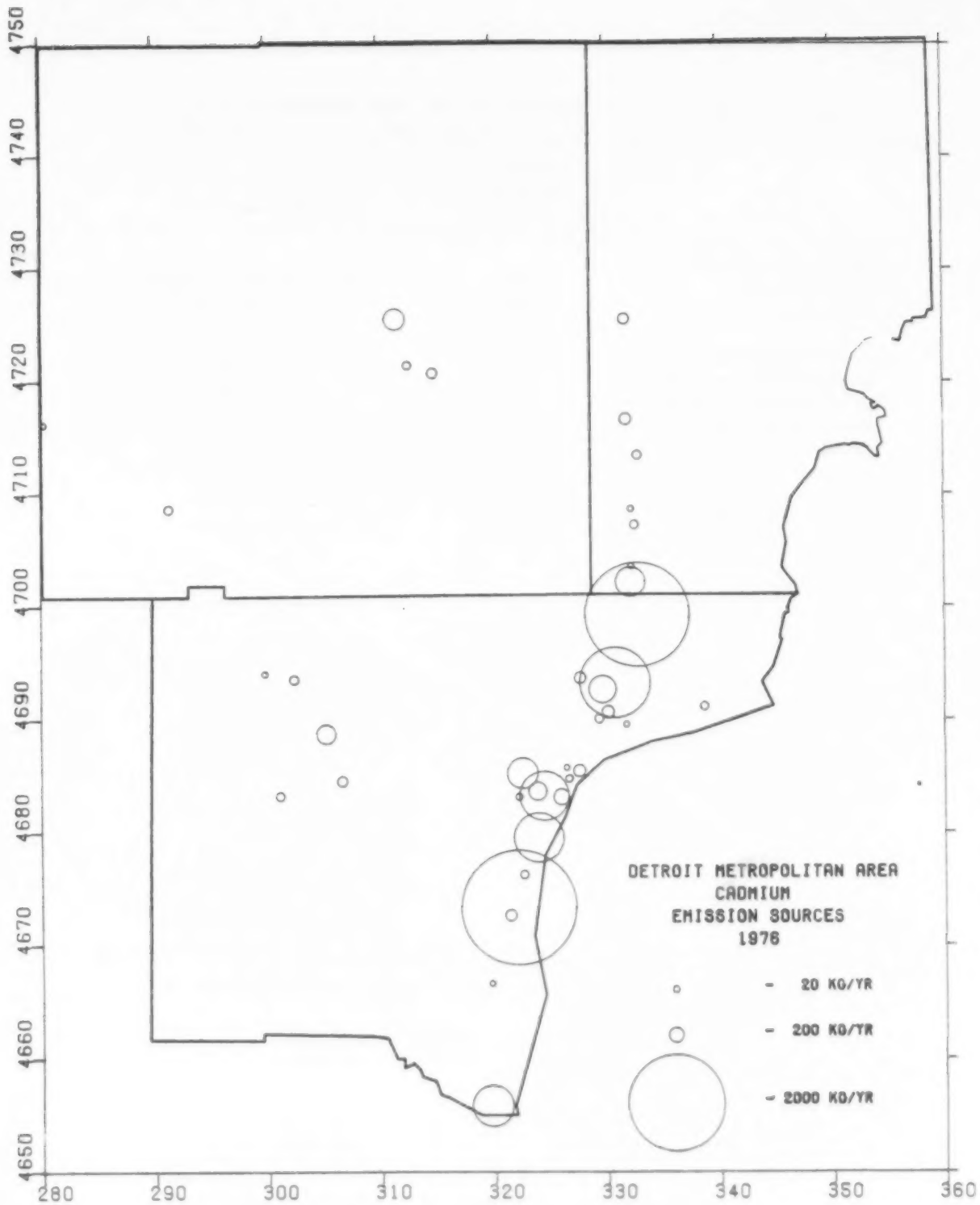

Figure 27. Sources of cadmium and their emissions, 1976.

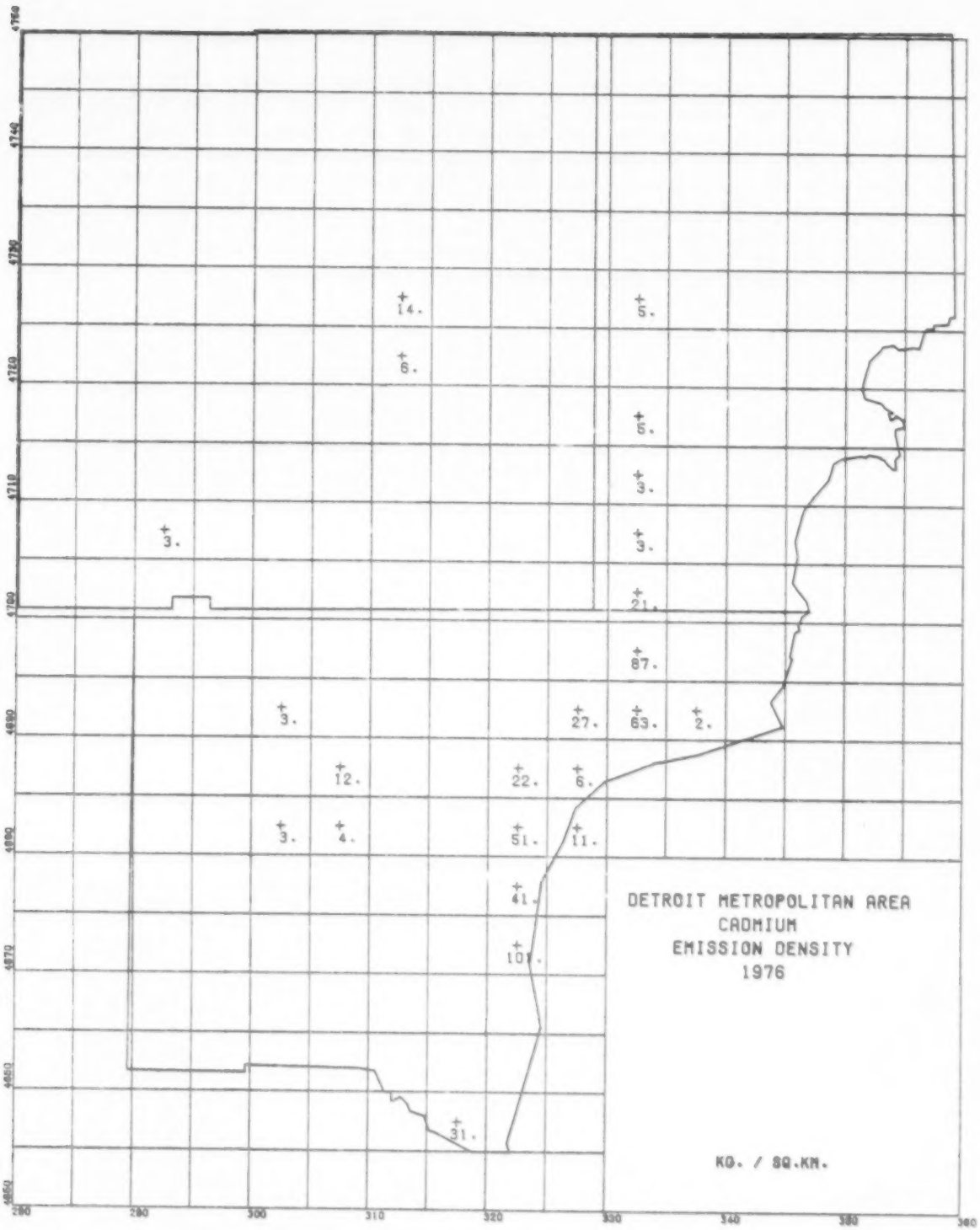

Figure 28. Cadmium emission density, 1976.

The ambient cadmium concentrations are measured at seven sites in Wayne County. Figure 29 shows the 1971 to 1976 trend at sites with the highest and lowest concentrations and the average values of all seven sites (detailed air quality data given in Appendix D). The concentrations have decreased, substantially in some cases, since 1971. The spatial variation in ambient concentrations on 1976 air quality data is shown in Figure 30. Again, as in the case of nickel, the number of sites is too few to put any great degree of confidence in the exact shape of the isopleths plotted in Figure 30, but it offers some insight into high and low concentration areas.

The concentration pattern in Figure 30 compares extremely well with emission sources and profiles given in Figures 27 and 28. Note that the high concentration areas are identical in both air quality and emissions plots. Since these air quality measurements and emission estimates are obtained independent of each other, similarities in the spatial patterns substantially increased the confidence of the exposure analysis. Figure 31 shows high and low exposure areas for cadmium which were determined based on ambient air quality concentration patterns and emission density patterns (Figures 30 and 28).

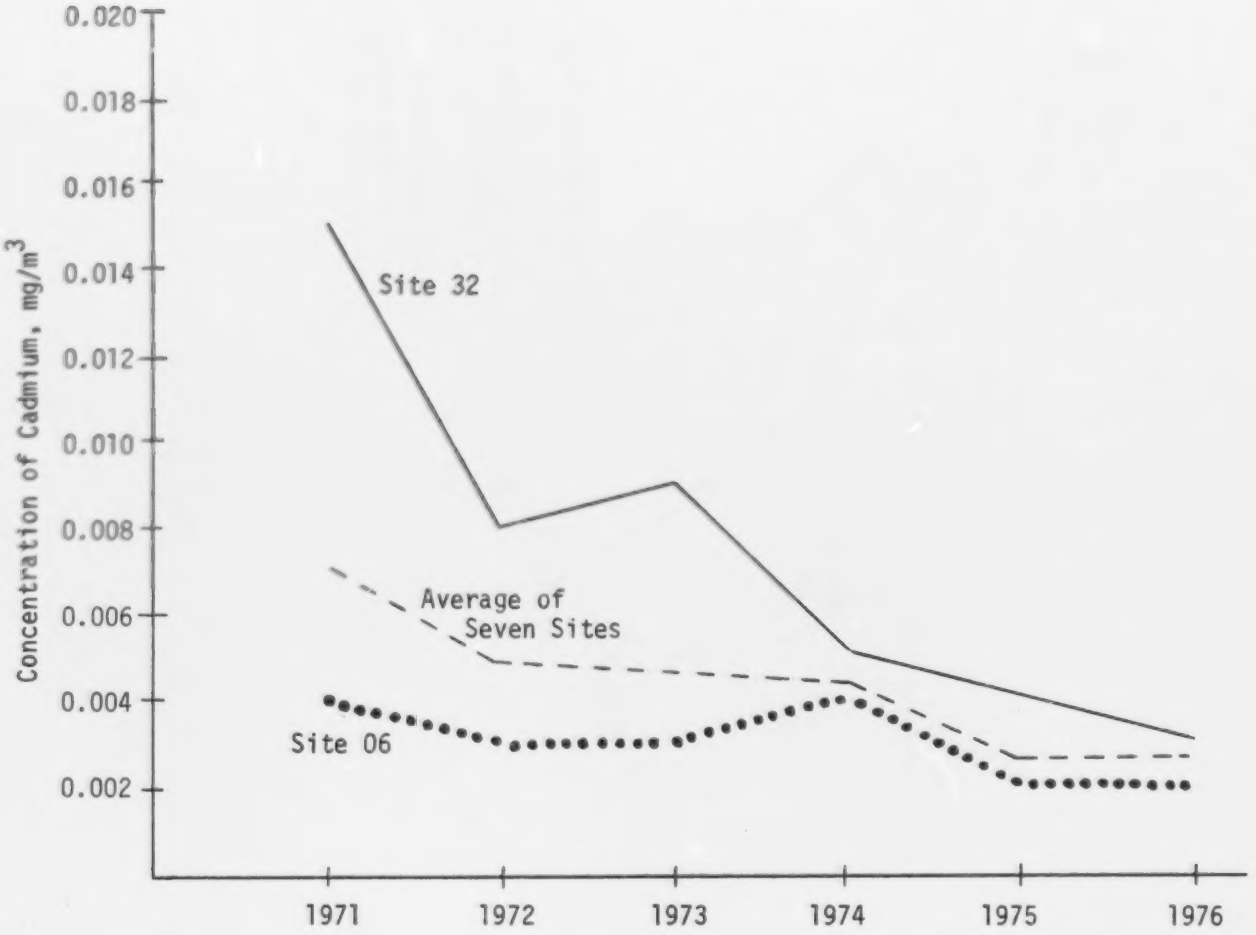

Figure 29. Ambient cadmium concentrations in the Detroit metropolitan study area, 1971-76.

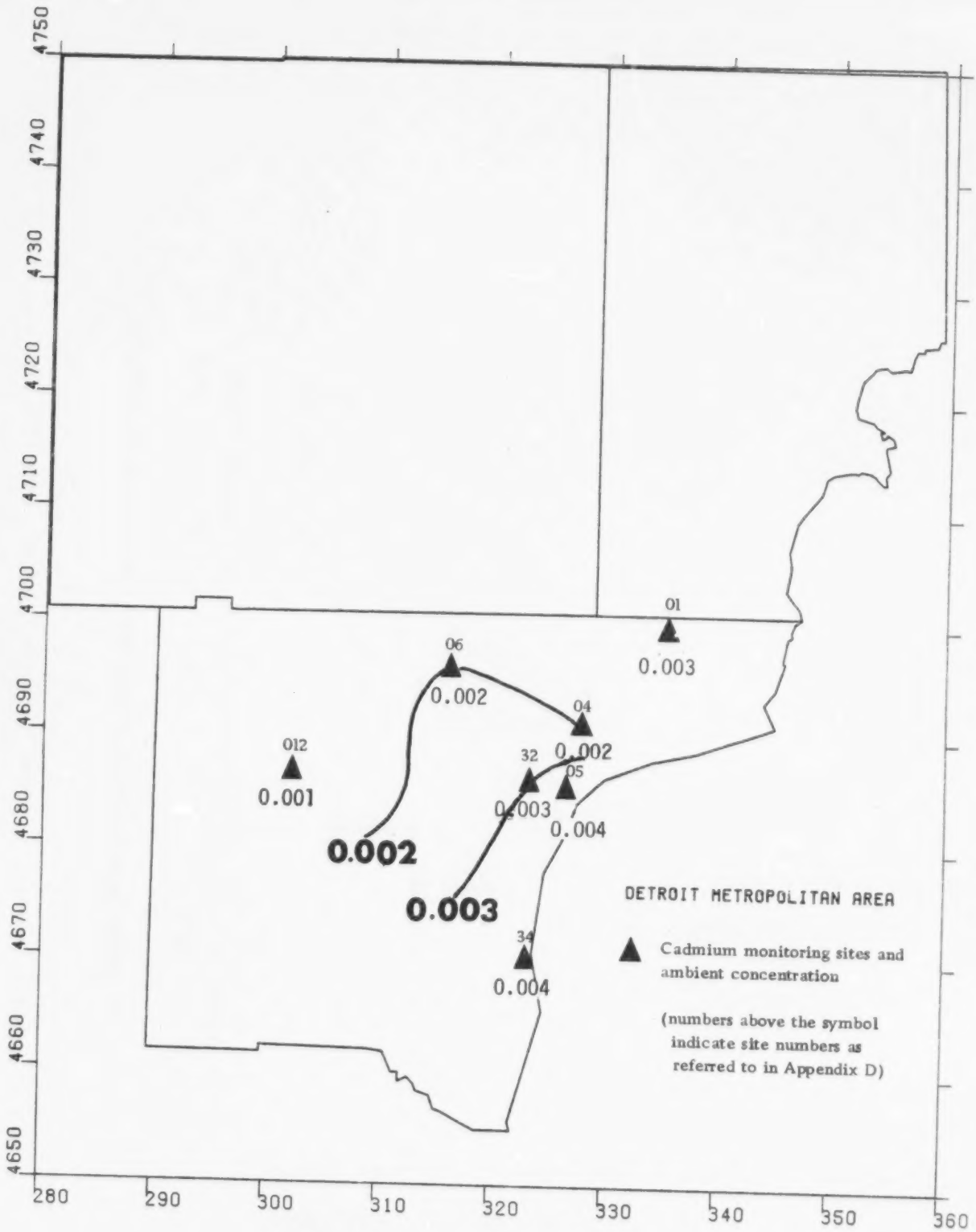

Figure 30. Ambient concentrations of cadmium, 1976.

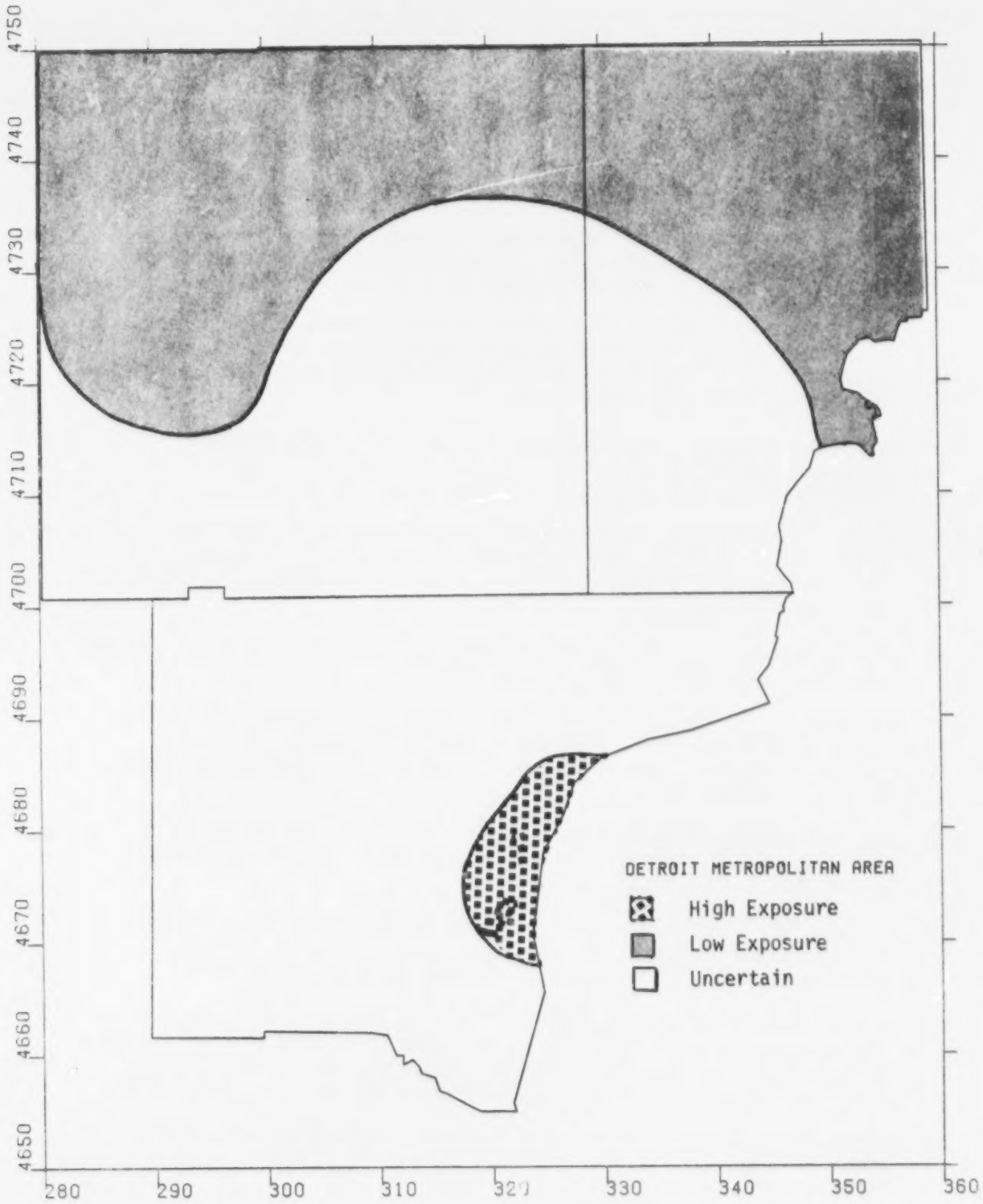

Figure 31. Characterization of ambient exposure to cadmium.

SECTION 5

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APPENDIX A

POINT-SOURCE DATA SYSTEM OF MICHIGAN DEPARTMENT OF NATURAL RESOURCES (MDNR)

The MDNR system consists of three separate data sets which describe source, business, and emissions information for each point source. Source and business files for all sources in Michigan were received on two separate tapes. The source data set contains information for each establishment on type of equipment, operational parameters, control equipment, fuel usage, stack parameters, and estimated emissions for certain pollutants (Table A-1). The equipment descriptions are included in Table A-2 and control equipment is listed in Table A-3.* The emission estimates are included in the data set if an establishment wishes to calculate its own emissions due to special circumstances such as unusual control equipment, proprietary processes, special processes stack studies, etc. The business data set includes information on physical location, owner, contact person, mailing address, etc. (Table A-4).

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* State of Michigan Department of Natural Resources, Reference Tables and General Instructions, 1976 Michigan Air Pollution Reporting Form. (These instructions are also useful in understanding elements of the MDNR data sets.)

TABLE A-1. ELEMENTS AND FORMAT OF MDNR SOURCE DATA SET (LRECL = 216)

Record Type	Field	Start Position	Length	Type
20	Record Type	1	2	N
	Identification:			
	Establishment	3	5	A
	SIC	8	4	N
	County*	12	2	N
	District	14	2	N
	FEE Region	16	1	N
	AQ Region	17	3	N
	Source I.D.	20	3	N
	Equipment Name	23	20	A
	Equipment Code†	43	4	N
	Number of Pieces	47	3	N
	Operating Schedule 1:			
	Hour-Day	50	2	N
	Day-Year	52	3	N
	Operating Schedule 2:			
	Percent Qtr. 1	55	3	N
	Percent Qtr. 2	58	3	N
	Percent Qtr. 3	61	3	N
	Percent Qtr. 4	64	3	N
	Rated Capacity:			
	Capacity Amount	67	9	D(2)
	Capacity Unit	76	1	N
	Material Processed:			
	Material Amount	77	9	D(2)
	Material Unit	86	1	N
	Control Equipment Codes: ††			
	Control 1	87	2	N
	Control 2	89	2	N
	Control 3	91	2	N
	Collection Efficiency	93	5	D(2)
	Natural Gas	98	9	N

(cont.)

* County codes: 50-Macomb, 63-Oakland, and 82-Wayne

† See Table A-2

†† See Table A-3

TABLE A-1. (Continued)

Record Type	Field	Start Position	Length	Type
20 (Con't)	Dist. Oil:			
	D.O.	107	9	N
	D.O. - Sulf.	116	3	D(2)
	Residual Oil:			
	R.O.	119	9	N
	R.O. - Sulf.	128	3	D(2)
	Wood	131	9	N
	Coal or Coke:			
	Coal	140	9	N
	C.L. - Sulf.	149	3	D(2)
	C.L. - Ash	152	4	D(2)
	Other Fuel:			
	Other	156	9	N
	O.T. - Sulf.	165	3	D(2)
	O.T. - Ash	168	4	D(2)
	Error Codes (Occurs 10 times)	172	10(2)	N
	Creation Date	192	8	A
	Change Date	200	8	A
	Indicators:			
	FEE Bypass	208	1	N
	Confidential	209	1	N
	Business Master	210	1	N
	Record Qual.	211	1	N
	Filler 20	212	5	A
24	Stack Key	1	22	A
	Stack Height	23	4	N
	Stack Dimensions:			
	Stack Length (ft.)	27	3	N
	Stack Length (in.)	30	2	N
	Stack Width (ft.)	32	3	N
	Stack Width (in.)	35	2	N
	Stack Diameter:			
	Stack Diameter (ft.)	37	3	N
	Stack Diameter (in.)	40	2	N

(cont.)

TABLE A-1. (Concluded)

Record Type	Field	Start Position		Length	Type
24 (Con't)	Stack Temperature	42		4	N
	Stack Velocity Flow Rates:				
	Stack Velocity - Low	46		8	N
	Stack Velocity - Normal	54		8	N
	Stack Velocity - Maximum	62		8	N
	Stack Source I.D.'s (12 Times)	70		12(3)	N
	Filler 24	106		66	A
	Filler	172		45	A
	SEE Key	1		22	A
	SEE Source I.D.	23		3	N
	SEE Equipment Name	26		20	A
	SEE Equipment Code	46		4	N
	SEE Estimates (Occurs 10 times):				
	SEE Pollutant	50	10	2	N
	SEE Emission	52		8	D(2)
	Filler 29	150		22	A
	Filler	172		45	A

TABLE A-2. EQUIPMENT DESCRIPTION INFORMATION

A PRODUCT	B PROCESS	C EQUIPMENT NAME	D EQUIP-MENT CODE NO.	E QUANTITY OF MATERIAL PROCESSED, HANDLED OR COLLECTED DURING 1976	F STACK DATA REQUIRED
		INCINERATION			
WASTE DISPOSAL	Open Burning	Open Burning	0001	Pounds or tons of waste burned	No
	Incinerators	Single Chamber	0005	Pounds or tons of waste burned	Yes
		Multiple Chamber	0006	Pounds or tons of waste burned	Yes
		Flue fed	0007	Pounds or tons of waste burned	Yes
		Controlled Air	0008	Pounds or tons of waste burned	Yes
		Conical Tee Pee	0009	Pounds or tons of waste burned	Yes
		Liquid waste	0010	Gallons of waste burned	Yes
		Municipal	0011	Pounds or tons of waste burned	Yes
		Multiple hearth—sewage sludge	0012	Pounds or tons of waste burned (dry solids only)	Yes
		Fluidized bed—sewage sludge	0013	Pounds or tons of waste burned (dry solids only)	Yes
		Other type	0014	Pounds or tons of waste burned	Yes
		BOILERS, TURBINES, WARM AIR FURNACES, ETC.			
HEATING, STEAM OR POWER GENERATION	Heating	Warm air furnaces—coal fired	0016	Not applicable	Yes
		Warm air furnaces—other fuels	0017	Not applicable	Yes
		Boilers without coal firing capability	0018	Not applicable	Yes
	Coal Burning Boilers	Hand fired	0019	Not applicable	Yes
		Underfeed stoker	0020	Not applicable	Yes
		Spreader stoker	0021	Not applicable	Yes
		Other type stoker	0022	Not applicable	Yes
		Pulverized corner fired	0023	Not applicable	Yes
		Pulverized other type	0024	Not applicable	Yes
		Cyclone type	0025	Not applicable	Yes
	Turbine Generators	Gas turbine—gas fired	0026	Not applicable	Yes
		Gas turbine—oil fired	0027	Not applicable	Yes
	Diesel Engine	Diesel engine—generator	0028	Not applicable	Yes
		MISCELLANEOUS EQUIPMENT (COMMON TO MANY ESTABLISHMENTS)			
MISCELLANEOUS	Organic Solvent Usage	Perchloroethylene	0030	Gallons evaporated	No
		Trichloroethylene	0031	Gallons evaporated	No
		Methylchloroform	0032	Gallons evaporated	No
		Mineral spirits, Naptha	0033	Gallons evaporated	No
		Methanol, Ethanol, Isopropanol	0034	Gallons evaporated	No
		Methyl—or Ethyl—Ketone	0035	Gallons evaporated	No
		Toluene, Xylene or mixtures	0036	Gallons evaporated	No
		Benzene	0037	Gallons evaporated	No
		All other types	0038	Gallons evaporated	No
	Solvent Based Coatings Applied by Spray Coating	Enamel (electrostatic spraying)	0040	Gallons used	No
		Enamel (other)	0041	Gallons used	No
		Lacquer (electrostatic spraying)	0042	Gallons used	No
		Lacquer (other)	0043	Gallons used	No
		Stains	0044	Gallons used	No
		Varnishes	0045	Gallons used	No
		Under coating	0046	Gallons used	No
		Inks	0047	Gallons used	No
		Adhesive	0048	Gallons used	No
		All other types	0049	Gallons used	No
	Solvent Based Coatings, Applied by Other Methods	Enamel	0050	Gallons used	No
		Lacquer	0051	Gallons used	No
		Stains	0052	Gallons used	No
		Varnishes	0053	Gallons used	No
		Under coating	0054	Gallons used	No
		Inks	0055	Gallons used	No
		Adhesives	0056	Gallons used	No
		All other types	0057	Gallons used	No
	Mixers & Blenders	Chemical & plastic compounds	0058	Tons of material processed	Yes

(cont.)

TABLE A-2. (Continued)

A PRODUCT	B PROCESS	C EQUIPMENT NAME	D EQUIP-MENT CODE NO.	E QUANTITY OF MATERIAL PROCESSED, HANDLED OR COLLECTED DURING 1976	F STACK DATA REQUIRED
	Abrasive Cleaning	Grinders, sand blasters, shot peeners (vented outside)	0060	Tons of material collected in dust collectors, (if no collector, estimate the amount of emissions)	Yes
		Buffers and polishers	0061	Tons of material collected in dust collectors, (if no collector, estimate the amount of emissions)	Yes
	Machining	Millers, borers, lathes	0063	Not applicable	No
	Welding & Brazing	Manual & automatic	0064	Not applicable	No
	Metal Cleaning	Degreaser tanks	0065	Gallons of solvent make-up	No
		Parts washers	0066	Gallons of make-up	No
	Blue Prints	Blue print machines (ammonia)	0067	Gallons of ammonia used	No
	Heating & Drying	Fuel powered heaters, ovens, furnaces, dryers, etc. Not listed elsewhere in this table. (Do not include steam or electric ovens)	0070	Not applicable	Yes
	Oil Quenching	Quench tanks (vented outside)	0071	Gallons of make-up	Yes
	Molten Salt Quench Tanks	Quench tanks (vented outside)	0072	Gallons of make-up	Yes
	Metal Plating	Plating tanks	0074	Not applicable	No
	Acid Pickling or Etching	Acid tanks	0075	Not applicable	No
	Other Acid Treatments	Acid tanks	0076	Not applicable	No
	Material Handling Systems	Conveyors, elevators, transfer stations, etc. Not listed elsewhere in this table.	0077	Tons of material handled	No
	Cooling	Material cooler not listed elsewhere in this table.	0078	Tons of material handled	No
	Engine Testing	Engine test stands	0079	Gallons of fuel consumed	No
		PRODUCT RECLAMATION			
WIRE	Reclaim	Reclaiming furnace	0080	Tons of wire reclaimed	Yes
STEEL DRUMS	Reclaim	Reclaiming furnace	0081	Number of barrels reclaimed	Yes
GRINDING WHEELS	Reclaim	Reclaiming furnace	0082	Tons of product reclaimed	Yes
MISCELLANEOUS METAL	Stripping	Kolene strip furnace	0083	Gallons of tank capacity	Yes
	Metal Fragmentizing	Fragmentizer	0084	Tons of metal fragmentized	No
WASTE OIL	Waste Oil Distilling	Stills	0085	Gallons of finished product produced	Yes
	Waste Oil Storage	Tanks	0086	Gallons of material stored	Yes
	Finished Product Storage	Tanks	0087	Gallons of material stored	Yes
		FOOD AND AGRICULTURAL			
FEED, GRAIN & GRAIN PRODUCTS	Grain Handling	Shipping and receiving docks	0100	Tons of total grain handled	Yes
	Grain Handling	Conveyor	0101	Tons of total grain handled	Yes
	Grain Handling	Screen	0102	Tons of total grain handled	Yes
	Grain Drying	Dryer, column	0103	Tons of total grain handled	Yes
	Grain Drying	Dryer, rack	0108	Tons of total grain handled	Yes
	Grain Drying	Dryer, drum	0109	Tons of total grain handled	Yes
	Grain Cleaning	Cleaner	0104	Tons of total grain handled	Yes
	Grain Milling	Mill	0105	Tons of total grain handled	Yes
	Grain Cooking	Cooker	0106	Tons of total grain handled	Yes
	Grain Mixing	Mixer	0107	Tons of total grain handled	Yes
MEAT	Meat Smoking	Smoke house	0120	Tons of meat smoked	Yes
	Rendering	Edible animal fats	0121	Tons rendered	Yes
	Rendering	Inedible animal fats	0122	Tons rendered	Yes
	Charbroiling	Charbroil Grill	0123	Tons of meat cooked	Yes
COFFEE	Roasting	Direct-fired roaster	0150	Tons of green beans roasted	Yes
	Roasting	Indirect-fired roaster	0151	Tons of green beans roasted	Yes
	Roasted Bean Cleaning	Stoner	0152	Tons of beans stoned	Yes
	Roasted Bean Cooling	Cooler	0153	Tons of beans cooled	Yes
	Instant Coffee Drying	Spray dryer	0154	Tons of green beans input	Yes
DRY MILK	Evaporation	Dryer	0160	Tons of dry milk produced	Yes
POTATO CHIPS	Cooking	Fryer	0170	Gallons of cooking oil used	Yes
POPCORN	Industrial Manufacture	Popper	0171	Tons of corn popped	Yes
SPICE	Spice Grinding	Spice mill	0180	Tons of spice processed	Yes

(cont.)

TABLE A-2. (Continued)

A PRODUCT	B PROCESS	C EQUIPMENT NAME	D EQUIP-MENT CODE NO.	E QUANTITY OF MATERIAL PROCESSED, HANDLED OR COLLECTED DURING 1976	F STACK DATA REQUIRED
BEET SUGAR	Pulp Drying	Pulp Dryer	0190	Tons of pulp dried	Yes
DIAMMONIUM PHOSPHATE FERTILIZER	Acidulation	Mixer	0200	Tons of fertilizer produced	Yes
	Acidulation	Den	0201	Tons of fertilizer produced	Yes
	Acidulation	Curing	0202	Tons of fertilizer produced	Yes
	Granulation	Ammoniator-granulator	0203	Tons of fertilizer granulated	Yes
	Granulation	Dryer	0204	Tons of fertilizer granulated	Yes
	Granulation	Cooler	0205	Tons of fertilizer granulated	Yes
NORMAL SUPER PHOSPHATE	Acidulation	Mixer	0220	Tons of fertilizer produced	Yes
	Acidulation	Den	0221	Tons of fertilizer produced	Yes
	Acidulation	Curing	0222	Tons of fertilizer produced	Yes
	Granulation	Ammoniator-granulator	0223	Tons of fertilizer granulated	Yes
	Granulation	Dryer	0224	Tons of fertilizer granulated	Yes
	Granulation	Cooler	0225	Tons of fertilizer granulated	Yes
TRIPLE SUPER PHOSPHATE FERTILIZER	Acidulation	Mixer	0240	Tons of fertilizer produced	Yes
	Acidulation	Den	0241	Tons of fertilizer produced	Yes
	Acidulation	Curing building	0242	Tons of fertilizer produced	Yes
	Granulation	Ammoniator-granulator	0243	Tons of fertilizer granulated	Yes
	Granulation	Dryer	0244	Tons of fertilizer granulated	Yes
	Granulation	Cooler	0245	Tons of fertilizer granulated	Yes
		MINERAL PRODUCTS			
ASPHALT ROOFING	Blowing	Blowing still	0300	Tons of saturated felt	Yes
	Dipping Only	Saturator	0301	Tons of saturated felt	Yes
	Spraying Only	Saturator	0302	Tons of saturated felt	Yes
	Combine Dipping & Spraying	Saturator	0303	Tons of saturated felt	Yes
ASPHALT BATCHING	General Process	Rotary Dryer, Screens, Conveyor, Mixer	0320	Tons of asphalt produced	Yes
CASTABLE REFRACTORY	Raw Material Dryer	Dryer	0340	Tons of material produced	Yes
	Raw Material Crushing & Grinding	Crushers & Grinders	0341	Tons of feed material	Yes
	Melting	Electric arc furnace	0342	Tons of feed material	Yes
	Curing	Oven	0343	Tons of feed material	Yes
	Casting Handling	Molding station	0344	Tons of feed material	Yes
	Casting Handling	Shakeout station	0345	Tons of feed material	Yes
CEMENT	Dry Process	Kiln (gas fired)	0360	Tons of cement produced	Yes
	Dry Process	Kiln (oil fired)	0361	Tons of cement produced	Yes
	Dry Process	Kiln (coal fired)	0362	Tons of cement produced	Yes
	Dry Process	Clinker Cooler	0363	Tons of cement produced	Yes
	Dry Process	Grinder	0364	Tons of cement produced	Yes
	Dry Process	Mill	0365	Tons of cement produced	Yes
	Wet Process	Kiln (gas fired)	0366	Tons of cement produced	Yes
	Wet Process	Kiln (oil fired)	0367	Tons of cement produced	Yes
	Wet Process	Kiln (coal fired)	0368	Tons of cement produced	Yes
	Wet Process	Clinker Cooler	0369	Tons of cement produced	Yes
	Wet Process	Grinder	0370	Tons of cement produced	Yes
	Wet Process	Mill	0371	Tons of cement produced	Yes
	General Material Handling	Conveying & transfer points	0372	Tons of cement produced	Yes
	General Material Handling	Hoppers, bins or silos	0373	Tons of cement produced	Yes
CONCRETE BATCHING	Mixing Wet	Mixer	0380	Cubic yards of concrete produced	Yes
	Mixing Dry	Mixer	0381	Cubic yards of concrete produced	Yes
	Transferring	Conveyor & elevator	0382	Cubic yards of concrete produced	Yes
	Storage	Bins & hoppers	0383	Cubic yards of concrete produced	Yes
GLASS	Soda Lime Process	Furnace	0400	Tons of glass produced	Yes
	Other (Specify)	Furnace	0401	Tons of glass produced	Yes
GYPSUM	Drying	Material dryer	0410	Tons of gypsum produced	Yes
	Grinding	Grinder	0411	Tons of gypsum produced	Yes
	Conveying	Conveyor & transfer points	0412	Tons of gypsum produced	Yes
	Calcining	Kettle	0413	Tons of gypsum produced	Yes
	Storage	Hoppers, Bins or Silos	0414	Tons of gypsum produced	Yes
LIME, DOLOMITE, & MAGNESIA	Primary Crushing	Primary mill	0420	Tons of material produced	Yes
	Secondary Crushing	Secondary mill	0421	Tons of material produced	Yes
	Calcining	Vertical kiln	0422	Tons of material produced	Yes
	Calcining	Horizontal kiln	0423	Tons of material produced	Yes
	Calcining	Multiple hearth calciner	0424	Tons of material produced	Yes
	Cooling	Rotary cooler	0425	Tons of material produced	Yes
	Storage	Hoppers, Bins or Silos	0426	Tons of material produced	Yes
PERLITE	Exfoliation	Vertical furnace	0430	Tons of perlite charged	Yes

(cont.)

TABLE A-2 (Continued)

A PRODUCT	B PROCESS	C EQUIPMENT NAME	D EQUIP-MENT CODE NO.	E QUANTITY OF MATERIAL PROCESSED, HANDLED OR COLLECTED DURING 1976	F STACK DATA REQUIRED
PHOSPHATE	Drying	Dryer	0440	Tons of phosphate rock processed	Yes
	Grinding	Grinder	0441	Tons of phosphate rock processed	Yes
	Conveying	Conveyor	0442	Tons of phosphate rock processed	Yes
	Open Storage	Storage pile	0443	Tons of phosphate rock processed	Yes
BRICK & CLAY PRODUCTS	Raw Material Handling	Dryers, Grinders, etc.	0450	Tons of product produced	Yes
	Raw Material Handling	Storage pile	0451	Tons of product produced	Yes
	Curing & Firing	Tunnel kiln (gas fired)	0452	Tons of product produced	Yes
	Curing & Firing	Tunnel kiln (oil fired)	0453	Tons of product produced	Yes
	Curing & Firing	Tunnel kiln (coal fired)	0454	Tons of product produced	Yes
	Curing & Firing	Periodic kiln (gas fired)	0455	Tons of product produced	Yes
	Curing & Firing	Periodic kiln (oil fired)	0456	Tons of product produced	Yes
	Curing & Firing	Periodic kiln (coal fired)	0457	Tons of product produced	Yes
STONE QUARRY	Primary Crushing	Primary crusher	0460	Tons of raw material	Yes
	Secondary Crushing	Secondary crusher	0461	Tons of raw material	Yes
	Tertiary Crushing	Tertiary crusher	0462	Tons of raw material	Yes
	Screening	Screen	0463	Tons of raw material	Yes
	Fines Milling	Mill	0464	Tons of raw material	Yes
	Conveying	Conveyor	0465	Tons of raw material	Yes
	Open Storage	Storage piles	0466	Tons of raw material	Yes
SAND & GRAVEL	Drying	Dryer	0470	Tons of product produced	Yes
	Cooling	Cooler	0471	Tons of product produced	Yes
	Crushing	Crusher	0472	Tons of product produced	Yes*
	Screening	Screen	0473	Tons of product produced	Yes
	Conveying	Conveyor & transfer point	0474	Tons of product produced	Yes
	Open Storage	Storage pile	0475	Tons of product produced	Yes
		WOOD PRODUCTS			
WOOD PULP OR PAPER	Sulfate Pulping	Blow tank accumulator	0500	Tons of air dried unbleached pulp	Yes
	Sulfate Pulping	Washers & screens	0501	Tons of air dried unbleached pulp	Yes
	Sulfate Pulping	Multiple effects evaporator	0502	Tons of air dried unbleached pulp	Yes
	Sulfate Pulping	Recovery boiler	0503	Tons of air dried unbleached pulp	Yes
	Sulfate Pulping	Direct contact evaporator	0504	Tons of air dried unbleached pulp	Yes
	Sulfate Pulping	Smelt dissolving tank	0505	Tons of air dried unbleached pulp	Yes
	Sulfate Pulping	Lime kiln	0506	Tons of air dried unbleached pulp	Yes
	Sulfate Pulping	Turpentine condenser	0507	Tons of air dried unbleached pulp	Yes
	Sulfate Pulping	Fluidized bed calciner	0508	Tons of air dried unbleached pulp	Yes
	Neutral Sulfite Pulp	Recovery boiler	0520	Tons of air dried pulp	Yes
	Neutral Sulfite Pulp	Sulfiting tower	0521	Tons of air dried pulp	Yes
	Neutral Sulfite Pulp	Blow tank	0522	Tons of air dried pulp	Yes
	Neutral Sulfite Pulp	Dissolving tank	0523	Tons of air dried pulp	Yes
	Neutral Sulfite Pulp	Evaporator	0524	Tons of air dried pulp	Yes
	Neutral Sulfite Pulp	Pulp washers	0525	Tons of air dried pulp	Yes
HARDBOARD	Drying	Coe dryer	0540	Tons of dry product	Yes
	Drying	Predryer	0541	Tons of dry product	Yes
	Pressing	Press	0542	Tons of dry product	Yes
	Tempering	Oilspray or flow coater	0543	Tons of dry product	Yes
	Baking	Bake oven	0544	Tons of product baked	Yes
PARTICLE BOARD	Drying	Flash dryer	0550	Tons of material dried	Yes
	Drying	Jet dryer	0551	Tons of material dried	Yes
	Pressing	Board press	0552	Tons of material pressed	Yes
MISCELLANEOUS WOOD PRODUCTS	Woodworking	Planers, saws, routers	0560	Tons of woodwaste collected in dust collector	Yes
	Woodworking	Sanders	0561	Tons of woodwaste collected in dust collector	Yes
PAPER AND CARDBOARD	Fabricating	Cutters and Shredders	0570	Tons of material collected in dust collectors, (if no collector, enter zero)	Yes
		SECONDARY METALS			
ALUMINUM	Sweating	Sweating furnace	0600	Tons of aluminum processed	Yes
	Smelting	Crucible furnace	0601	Tons of aluminum processed	Yes
	Smelting	Reverbratory furnace	0602	Tons of aluminum processed	Yes
	Chlorination	Chlorination station	0603	Tons of chlorine used	Yes
	Metal Holding	Holding furnace	0604	Tons of aluminum processed	Yes
	Melting (No Flux)	Furnace (All types)	0605	Tons of aluminum processed	Yes
BRASS & BRONZE	Melting	Blast furnace	0610	Tons of brass or bronze charged	Yes
	Melting	Crucible furnace	0611	Tons of brass or bronze charged	Yes
	Melting	Cupola	0612	Tons of brass or bronze charged	Yes
	Melting	Electric induction furnace	0613	Tons of brass or bronze charged	Yes
	Melting	Reverbratory furnace	0614	Tons of brass or bronze charged	Yes
	Melting	Rotary furnace	0615	Tons of brass or bronze charged	Yes
	Chip Drying	Kiln	0616	Tons of brass or bronze charged	Yes
	Metal Holding	Holding furnace (any type)	0617	Tons of brass or bronze charged	Yes

(cont.)

TABLE A-2. (Continued)

A PRODUCT	B PROCESS	C EQUIPMENT NAME	D EQUIP-MENT CODE NO.	E QUANTITY OF MATERIAL PROCESSED, HANDLED OR COLLECTED DURING 1976	F STACK DATA REQUIRED
IRON	Melting	Cupola	0620	Tons of iron charged	Yes
	Melting	Reverbratory furnace	0621	Tons of iron charged	Yes
	Melting	Electric arc furnace	0622	Tons of iron charged	Yes
	Melting	Electric induction furnace	0623	Tons of iron charged	Yes
	Metal Holding	Holding furnace (any type)	0624	Tons of iron charged	Yes
STEEL	Melting	Electric arc furnace	0630	Tons of steel processed	Yes
	Melting	Electric induction furnace	0631	Tons of steel processed	Yes
	Melting with Oxygen Lance	Open hearth furnace	0632	Tons of steel processed	Yes
	Melting without Oxygen Lance	Open hearth furnace	0633	Tons of steel processed	Yes
	Metal Holding	Holding furnace (any type)	0634	Tons of steel processed	Yes
ALLOY STEEL	Melting	Electric Arc Furnace	0637	Tons of alloy steel processed	Yes
LEAD	Smelting	Pot furnace	0640	Tons of lead processed	Yes
	Smelting	Reverbratory furnace	0641	Tons of lead processed	Yes
	Smelting	Blast (cupola) furnace	0642	Tons of lead processed	Yes
	Smelting	Rotary reverbratory furnace	0643	Tons of lead processed	Yes
	Melting (No Flux)	Furnace (All types)	0644	Tons of lead processed	Yes
MAGNESIUM	Smelting	Pot furnace	0650	Tons of magnesium processed	Yes
	Melting (No Flux)	Furnace (All types)	0651	Tons of magnesium processed	Yes
ZINC	Smelting	Retort furnace	0661	Tons of zinc processed	Yes
	Smelting	Horizontal muffle furnace	0662	Tons of zinc processed	Yes
	Smelting	Pot furnace	0663	Tons of zinc processed	Yes
	Smelting	Sweating furnace	0664	Tons of zinc processed	Yes
	Galvanizing Kettle	Galvanizing kettle	0665	Tons of zinc processed	Yes
	Calcining	Calcine kiln	0666	Tons of zinc processed	Yes
	Melting (No Flux)	Furnace (All types)	0667	Tons of zinc processed	Yes
AUXILIARY CASTING PROCESSES	Foundry Sand Handling	Sand dryer	0669	Tons of sand handled	Yes
	Foundry Sand Handling	Sand silo	0670	Tons of sand handled	Yes
	Foundry Sand Handling	Muller	0671	Tons of sand handled	Yes
	Foundry Sand Handling	Shell core machines	0672	Tons of cores produced	Yes
	Foundry Sand Handling	Core oven	0673	Gallons of core oil used	Yes
	Foundry Sand Handling	Conveyors & elevators	0674	Tons of sand handled	Yes
	Foundry Sand Handling	Shakeout machine	0675	Tons of sand handled	Yes
	Foundry Sand Handling	Sand screens	0676	Tons of sand handled	Yes
	Foundry Sand Handling	Other core machines	0681	Tons of cores produced	Yes
	Foundry Sand Handling	Casting knock out	0682	Tons of sand handled	Yes
	Metal Pouring	Pouring station or area	0677	Tons of sand handled	Yes
	Casting Cleaning	Tumblers	0678	Tons of castings cleaned	Yes
	Casting Cleaning	Chippers	0679	Tons of castings cleaned	Yes
	Investment Castings	Wax burn out	0680	Tons of wax burned	Yes
		PRIMARY METALS			
COKE	By-Product Process	Coke battery	0700	Tons of coal charged	Yes
	Beehive Process	Beehive oven	0701	Tons of coal charged	Yes
	Coke Crushing	Crusher	0702	Tons of coal charged	Yes
	Coke Screening	Screens	0703	Tons of coal charged	Yes
IRON ORE	Pelletizing	Kiln	0710	Tons of ore processed	Yes
	Ore Handling	Conveyors, transfer, & loading facilities	0711	Tons of ore processed	Yes
IRON	Ore Reduction	Ore charged blast furnace	0720	Tons of iron produced	Yes
	Agglomerates Reduction	Agglomerates charged blast furnace	0721	Tons of iron produced	Yes
	Sintering	Sintering furnace	0722	Tons of iron produced	Yes
STEEL	Steel Production with Oxygen Lance	Open hearth furnace	0740	Tons of steel produced	Yes
	Steel Production with Oxygen Lance	Electric arc furnace	0741	Tons of steel produced	Yes
	Steel Production	Basic Oxygen Furnace	0742	Tons of steel produced	Yes
	Steel Production without Oxygen Lance	Open hearth furnace	0743	Tons of steel produced	Yes
	Steel Production without Oxygen Lance	Electric arc furnace	0744	Tons of steel produced	Yes
	Scarfing	Scarfer	0745	Tons of steel produced	Yes
COPPER	Roasting	Roaster	0760	Tons of concentrated ore	Yes
	Smelting	Furnace	0761	Tons of concentrated ore	Yes
	Converting	Converter	0762	Tons of concentrated ore	Yes
	Refining	Reverbratory furnace	0763	Tons of concentrated ore	Yes
	Holding	Holding furnace	0764	Tons of concentrated ore	Yes

(cont.)

TABLE A-2. (Concluded)

A PRODUCT	B PROCESS	C EQUIPMENT NAME	D EQUIPMENT CODE NO.	E QUANTITY OF MATERIAL PROCESSED, HANDLED OR COLLECTED DURING 1976	F STACK DATA REQUIRED
		CHEMICAL AND PETROLEUM MANUFACTURING			
AMMONIA	Converting	Purge gas exit	0800	Tons of ammonia produced	Yes
	Processed with CO Absorber	Regenerator exit	0801	Tons of ammonia produced	Yes
	Storage & Loading	Tanks	0802	Tons of ammonia stored	Yes
HYDROCHLORIC ACID	By-Product Process	Final exhaust	0820	Tons of final acid	Yes
NITRIC ACID	Ammonia—Oxidation	Final exhaust	0840	Tons of pure acid (100%)	Yes
	H_2NO_3—Concentration	Concentrator	0841	Tons of pure acid (100%)	Yes
SULFURIC ACID	Conversion of SO_2 to SO_3				
	93%	Waste gas exit stack	0880	Tons of H_2SO_4 produced (100%)	Yes
	94%	Waste gas exit stack	0881	Tons of H_2SO_4 produced (100%)	Yes
	95%	Waste gas exit stack	0882	Tons of H_2SO_4 produced (100%)	Yes
	96%	Waste gas exit stack	0883	Tons of H_2SO_4 produced (100%)	Yes
	97%	Waste gas exit stack	0884	Tons of H_2SO_4 produced (100%)	Yes
	98%	Waste gas exit stack	0885	Tons of H_2SO_4 produced (100%)	Yes
	99%	Waste gas exit stack	0886	Tons of H_2SO_4 produced (100%)	Yes
	99.5%	Waste gas exit stack	0887	Tons of H_2SO_4 produced (100%)	Yes
	99.7%	Waste gas exit stack	0888	Tons of H_2SO_4 produced (100%)	Yes
	100%	Waste gas exit stack	0889	Tons of H_2SO_4 produced (100%)	Yes
PAINT	Mixing	Mixing tank—dry	0900	Tons of pigment used	Yes
		Mixing tank—wet	0901	Tons of pigment used	Yes
	Solvent Storage	Tanks	0902	Tons of solvent stored	Yes
	Pigment Preparation	Grinders, Millers	0903	Tons of material collected in dust collectors (if no collector, enter zero)	Yes
VARNISH	Cooking—Bodying Oil	Cooking tank	0920	Tons of bodying oil produced	Yes
	Cooking—Oleoresinous	Cooking tank	0921	Tons of oleoresinous oil produced	Yes
	Cooking—Alkyd	Cooking tank	0922	Tons of alkyd produced	Yes
	Cooking—Acrylic	Cooking tank	0923	Tons of acrylic produced	Yes
	Cooking—Alkyd	Reactor Vessel	0924	Tons of alkyd produced	Yes
	Cooking—Acrylic	Reactor Vessel	0925	Tons of acrylic produced	Yes
	Solvent Storage	Tanks	0926	Tons of solvent stored	Yes
CHLOR-ALKALI	Liquefaction	Diaphram cell	0940	Tons of chlorine liquified	Yes
	Liquefaction	Mercury cell	0941	Tons of chlorine liquified	Yes
	Loading of Chlorine	Tank car vent	0942	Tons of chlorine liquified	Yes
	Loading of Chlorine	Storage tank vent	0943	Tons of chlorine liquified	Yes
	Air Blowing of Mercury Cell Brine	Air blow exit vent	0944	Tons of chlorine liquified	Yes
PRINTING INK	Vehicle Cooking-Oil	Cooking kettles	0960	Tons of oil based ink	Yes
	Vehicle Cooking-Oleoresinous	Cooking kettles	0961	Tons of oleoresinous based ink	Yes
	Vehicle Cooking-Alkyds	Cooking kettles	0962	Tons of alkyd based ink	Yes
	Pigment Mixing	Mixing facilities	0963	Tons of total ink produced	Yes
PETROLEUM PRODUCTS	Catalytic Cracking	Fluid cracking unit	0980	Barrels of fresh feed	Yes
	Catalytic Cracking	Moving bed cracking unit	0981	Barrels of fresh feed	Yes
	Compressing	Internal combustion engine	0982	1000 cubic feet gas burned	Yes
	General Process	Blow down systems (includes: pipeline-valves, relief valves, pumpseals, compressor seals, air blowers etc.)	0983	Barrels of refinery capacity	Yes
	General Process	Process drains	0984	Barrels of waste water	Yes
	General Process	Vacuum jets	0985	Barrels of vacuum distillate	Yes
	General Process	Cooling towers	0986	Gallons cooling water	Yes
	General Process	Miscellaneous heaters	0987	Not applicable	Yes
	Desulfurization	Sulfur recover unit	0989	Tons of sulfur removed	Yes
	Storage	Fixed roof tank (gasoline or finished product)	0990	Barrels of product stored	Yes
	Storage	Fixed roof tank (crude oil)	0991	Barrels of crude oil stored	Yes
	Storage	Floating roof tank (gasoline or finished product)	0992	Barrels of product stored	Yes
	Storage	Floating roof tank (crude oil)	0993	Barrels of crude oil stored	Yes
	Flaring	Hydrocarbon	0994	1000 cubic feet of gas burned	Yes
	Flaring	Hydrogen sulfide	0995	Tons H_2S burned	Yes
		ALL OTHER POINT SOURCES			
	Other sources	Not listed elsewhere	0999	Appropriate quantity of material	Yes

TABLE A-3. EMISSION CONTROL EQUIPMENT CODES

CODE	NAME
00	No control equipment used
01	Settling chamber
02	Single cyclone
03	Multicyclone
04	Other centrifugal type
05	Scrubber with water
06	Scrubber with solution
07	Venturi
08	Oil filter
09	Condenser
10	Fabric filter
11	Afterburner
12	Catalytic burner
13	Electrostatic precipitator
14	Primary burner
15	Wet baffle

TABLE A-4. ELEMENTS AND FORMAT OF MDNR BUSINESS DATA SET (LRECL = 360)

Field	Start Position	Length	Type
Record Type	1	2	N
Identification:			
Establishment	3	5	A
SIC	8	4	N
County	12	2	N
District	14	2	N
FEE Region	16	1	N
AQ Region	17	3	N
Physical:			
Business Name	20	28	A
Plant Name	48	28	A
Street Number	76	7	N
Street Name	83	20	A
City	103	20	A
Zip	123	5	N
Owner	128	28	N
Person	156	20	A
Phone Number	176	10	N
FEE ID	186	9	A
Number of Employees	195	5	N
Mailing Information:			
Line 1	200	30	A
Line 2	230	30	A
Street	260	30	A
City	290	20	A
State	310	5	A
Zip	315	5	A
Business Flags:			
Mailing Address	320	1	N
Old Establishment	321	5	A
Plan Region	326	2	N
FEE Bypass	328	1	N
Sec. County	329	3	N
Creation Date	332	8	A
Change Date	340	1	N
3000 Sq. Ft.	348	1	N
Asterisk	349	1	A
Confidential	350	1	A
Filler	351	10	A

Appendix B

HOUSING DATA AND FACTORS FOR ESTIMATION OF 1955 RESIDENTIAL COAL CONSUMPTION

County	Community	Occupied Dwelling Units		Community population shift factor* for 1955/1970	Correction factor**
		1955	1970		
Macomb	Armada	330	375	1.91	22.97
	Armada Twp.	340	422	1.75	21.03
	Bruce Twp.	320	561	1.24	14.89
	Centerline	2,300	3,095	1.62	19.4
	Chesterfield Twp.	1,300	2,626	1.08	12.92
	Clinton Twp.	4,100	13,026	0.68	8.22
	E. Detroit	9,500	13,077	1.58	18.96
	Fraser	520	3,006	0.38	4.51
	Grosse Pt. Shores (in St. Claire Shores)	--	(43)	--	--
	Harrison Twp.	2,250	5,519	0.89	10.64
	Lenox Twp.	550	739	1.62	19.42
	Macomb Twp.	1,000	1,602	1.36	16.29
	Memphis	200	211	2.06	24.74
	Mount Clemens	5,850	6,588	1.93	23.18
	New Baltimore	670	1,169	1.25	14.96
	New Haven	330	500	1.44	17.23
	Ray Twp.	510	707	1.57	18.83
	Richmond	720	953	1.64	19.72
	Richmond Twp.	340	429	1.72	20.69
	Romeo	990	1,170	1.84	22.08
	Roseville + Irin	10,760	16,453	1.42	17.07
	Shelby Twp.	2,750	7,405	0.81	9.69
	Sterling Heights	2,250	16,325	0.3	3.60

(continued)

* Community population shift factor is given by

$$\left[\frac{DU_{\text{community, 1955}}}{DU_{\text{community, 1970}}}\right] \times \left[\frac{DU_{\text{county, 1970}}}{DU_{\text{county, 1955}}}\right],$$

where DU is the number of occupied dwelling units.

** Correction factor for 1955 is equal to

$$\frac{CC_{\text{county, 1955}}}{CC_{\text{county, 1970}}} \times \left(\text{community population shift factor}\right),$$

where CC is residential coal consumption.

APPENDIX B. (continued)

County	Community	Occupied Dwelling Units 1955	Occupied Dwelling Units 1970	Community population shift factor * for 1955/1970	Correction factor **
Macomb (continued)	St. Claire Shores (plus Grosse Pt. Sh.)	13,800	24,597	1.22	14.64
	Utica	470	1,149	0.89	10.68
	Warren and War. Vil.	16,200	48,595	0.73	8.70
	Washington	645	1,500	0.94	11.22
	Total number of dwelling units in Macomb	78,995	171,799		
Oakland	Addison Twp.	350	785	0.76	18.31
	Anon Twp.	3,150	6,037	0.89	21.43
	Berkley	6,100	6,354	1.64	39.42
	Beverly Hills	--	3,753	--	--
	Bingham Farms	--	157	--	--
	Birmingham	7,000	8,636	1.38	33.29
	Bloomfield Hills	490	1,053	0.79	19.11
	Bloomfield Twp.	3,200	11,354	0.48	11.57
	Brandon Twp.	580	999	0.99	23.84
	Clarkston	240	348	1.18	28.32
	Clawson	3,050	4,779	1.09	26.21
	Commerce Twp.	1,900	3,839	0.84	20.32
	Farmington (City)	1,330	3,132	0.72	17.44
	Farmington Hills (Twp.)	4,300	13,363	0.55	13.21
	Ferndale	9,400	10,197	1.57	37.86
	Franklin	500	919	0.93	22.34
	Groveland Twp.	340	709	0.82	19.69
	Hazel Park	6,600	7,201	1.56	37.64
	Highland Twp.	1,100	2,304	0.81	19.61
	Holly Village	900	1,270	1.21	29.10
	Holly Twp.	450	897	0.85	20.60
	Huntington Woods	2,250	2,478	1.55	37.29
	Independence Twp.	1,500	4,212	0.61	14.62
	Keego Harbor	800	1,001	1.36	32.82
	Lake Angelus	50	160	0.53	12.83
	Lake Orion	850	914	1.58	38.19
	Lathrup Village	850	1,321	1.10	26.42
	Leonard	130	116	1.19	46.02
	Lyon Twp.	540	1,344	0.68	16.50
	Madison Heights	5,200	10,963	0.81	19.48
	Milford	680	1,325	0.87	21.08
	Milford Twp.	400	645	1.06	25.47

(continued)

APPENDIX B. (continued)

County	Community	Occupied Dwelling Units 1955	Occupied Dwelling Units 1970	Community population shift factor * for 1955/1970	Correction factor **
Oakland (continued)	Northville	--	566	--	--
	Novi	1,400	2,676	0.89	21.48
	Oakland Twp.	510	1,197	0.73	17.50
	Oak Park	7,700	10,940	1.20	28.90
	Orchard Lake	290	410	1.21	29.05
	Orion Twp.	1,900	4,708	0.69	16.57
	Ortonville	240	278	1.47	35.45
	Oxford	750	782	1.63	39.39
	Oxford Twp.	610	1,640	0.63	15.27
	Pleasant Ridge	1,160	1,196	1.65	39.83
	Pontiac	22,700	25,581	1.51	36.44
	Pontiac Twp.	2,100	3,801	0.94	22.69
	Rochester	1,500	2,541	1.01	24.24
	Rose Twp.	390	668	0.99	23.98
	Royal Oak	19,400	27,823	1.19	28.63
	Royal Oak Twp.	2,300	2,350	1.67	40.19
	Southfield	8,200	24,073	0.58	13.99
	South Lyon	470	753	1.06	25.63
	Springfield Twp.	620	1,196	0.88	21.29
	Sylvan Lake	540	697	1.32	31.82
	Troy	4,000	12,195	0.56	13.47
	Walled Lake	450	1,065	0.72	17.35
	Waterford Twp.	9,600	16,829	0.97	23.43
	West Bloomfield Twp.	2,600	7,333	0.60	14.56
	White Lake Twp.	1,760	4,025	0.75	17.96
	Wixom	--	608	--	--
	Wolverine Lake	500	1,155	0.74	17.78
	Total number of dwelling units in Oakland	155,920	265,741		
Wayne	Allen Park	8,600	11,489	0.81	6.90
	Belleville	580	830	0.76	6.44
	Brownstown Twp.	2,100	3,103	0.73	6.24
	Canton Twp.	1,300	3,261	0.43	3.67
	Dearborn	32,800	34,614	1.03	8.73
	Dearborn Heights	8,200	22,481	0.40	3.36
	Detroit	543,000	498,621	1.18	10.03
	Ecorse	4,700	5,326	0.96	8.13

(continued)

APPENDIX B. (continued)

County	Community	Occupied Dwelling Units		Community population shift factor * for 1955/1970	Correction factor **
		1955	1970		
Wayne (continued)	Flat Rock	990	1,554	0.69	5.87
	Garden City	6,300	10,482	0.65	5.54
	Gibraltar	600	1,106	0.59	5.0
	Grosse Ile Twp.	1,400	2,297	0.66	5.62
	Grosse Pointe	2,100	2,293	0.99	8.44
	Grosse Pointe Farms	3,400	3,732	0.99	8.39
	Grosse Pointe Park	4,400	4,823	0.99	8.41
	Grosse Pointe Shs.	445	904	0.53	4.54
	Grosse Pointe Woods	4,700	6,391	0.80	6.78
	Hamtramck	11,950	10,138	1.28	10.86
	Harper Woods	4,950	6,402	0.84	7.12
	Highland Park	14,350	12,412	1.25	10.65
	Huron Twp.	1,630	2,099	0.84	7.16
	Inkster	8,100	10,443	0.84	7.15
	Lincoln Park	12,800	15,999	0.87	7.37
	Linonia	10,500	27,686	0.41	3.49
	Melvindale	3,300	4,403	0.81	6.91
	Northville	1,060	1,082	1.06	9.03
	Northville Twp.	770	1,762	0.47	4.03
	Plymouth	2,450	3,762	0.71	6.00
	Plymouth Twp.	1,460	4,909	0.32	2.74
	Redford Twp.	14,600 •	19,759	0.80	6.81
	River Rouge	5,750	5,090	1.22	10.41
	Riverview	1,400	2,951	0.51	4.37
	Rockwood	330	885	0.40	3.44
	Romulus	3,700	6,574	0.61	5.19
	Southgate (Ecorse) Twp.	5,500	9,189	0.65	5.51
	Sumpter Twp.	1,150	2,173	0.57	4.88
	Taylor	7,500	18,498	0.44	3.74
	Trenton	2,950	6,530	0.49	4.16
	Van Buren Twp.	2,100	3,590	0.63	5.39
	Wayne	3,750	5,998	0.68	5.76
	Westland (Nankin)	7,300	23,046	0.34	2.92
	Woodhaven	--	--	--	--
	Wyandotte	12,100	12,922	1.02	8.63
	Total number of dwelling units in Wayne	767,085	831,609		

TABLE C-1. BaP EMISSIONS DATA FOR THE DETROIT METROPOLITAN AREA

SOURCE NUMBER	SOURCE LOCATION (KILOMETERS) HORIZONTAL	VERTICAL	SOURCE AREA SQUARE KILOMETERS	ANNUAL SOURCE EMISSION RATE (Tons x 10^3/day) 1956-1960	1975-1976	STACK DATA HT (M)	DIAM (M)	VEL (M/SEC)	TEMP (DEG.K)	ID # S	P
1	332.1	4698.3	0.0	0.009	0.001	18.3	0.0	0.0	436.	K525	K525
2	316.0	4685.3	0.0	0.010	0.001	18.3	0.0	0.0	436.	K575	K575
3	321.2	4696.9	0.0	0.011	0.001	18.3	0.0	0.0	436.	K741	K741
4	332.7	4695.0	0.0	0.014	0.002	18.3	0.0	0.0	436.	K773	K773
5	325.4	4695.0	0.0	0.014	0.002	18.3	0.0	0.0	436.	L107	L107
6	318.5	4689.0	0.0	0.011	0.001	19.8	0.0	0.0	450.	L109	L109
7	315.7	4690.6	0.0	0.008	0.001	18.3	0.0	0.0	436.	L110	L110
8	315.1	4696.9	0.0	0.013	0.002	18.3	0.0	0.0	436.	L117	L117
9	316.4	4699.6	0.0	0.011	0.001	18.3	0.0	0.0	436.	L118	L118
10	316.8	4700.2	0.0	0.012	0.001	15.3	0.0	0.0	450.	L118	L118
11	319.2	4693.2	0.0	0.012	0.001	18.3	0.0	0.0	436.	L123	L123
12	337.0	4692.4	0.0	0.010	0.001	21.3	0.0	0.0	436.	L125	L125
13	333.9	4691.7	0.0	0.010	0.001	18.3	0.0	0.0	436.	L125	L125
14	334.3	4694.0	0.0	0.010	0.001	18.3	0.0	0.0	436.	L125	L125
15	333.4	4693.9	0.0	0.014	0.002	18.3	0.0	0.0	436.	L125	L125
16	324.8	4686.4	0.0	0.013	0.002	18.3	0.0	0.0	436.	L130	L130
17	339.9	4696.1	0.0	0.012	0.001	18.3	0.0	0.0	436.	M325	M325
18	322.7	4676.2	0.0	0.004	0.002	69.8	2.1	0.0	422.	B280	B280
19	319.5	4691.2	0.0	0.032	0.004	18.3	0.0	0.0	436.	L116	L116
20	337.6	4692.1	0.0	0.018	0.002	18.3	0.0	0.0	436.	L124	L124
21	317.5	4695.6	0.0	0.012	0.001	30.0	0.0	0.0	0.	K787	K787
22	329.2	4695.0	0.0	0.050	0.006	30.0	0.0	0.0	0.	L091	L091
23	332.2	4691.3	0.0	0.047	0.005	30.0	0.0	0.0	0.	L093	L093
24	331.2	4690.5	0.0	0.036	0.004	30.0	0.0	0.0	0.	L093	L093
25	324.8	4691.0	0.0	0.041	0.005	30.0	0.0	0.0	0.	L094	L094
26	327.5	4686.5	0.0	0.013	0.002	30.0	0.0	0.0	0.	L096	L096
27	326.4	4685.2	0.0	0.028	0.003	30.0	0.0	0.0	0.	L097	L097
28	322.9	4691.2	0.0	0.025	0.003	30.0	0.0	0.0	0.	L109	L109
29	355.0	4692.0	0.0	0.032	0.004	30.0	0.0	0.0	0.	L125	L125
30	334.8	4692.8	0.0	0.013	0.002	30.0	0.0	0.0	0.	L141	L141

(Continued)

TABLE C-1. (Continued)

SOURCE NUMBER	SOURCE LOCATION (KILOMETERS) HORIZONTAL	VERTICAL	SOURCE AREA SQUARE KILOMETERS	ANNUAL SOURCE EMISSION RATE (Tons x 10^3/day) 1956-1960	1975-1976	STACK DATA HT (M)	DIAM (M)	VEL (M/SEC)	TEMP (DEG.K)	ID # S	P
31	322.2	4673.3	0.0	0.001	0.001	30.0	0.0	0.0	0.	B400	B400
32	322.2	4673.3	0.0	0.001	0.001	61.0	3.1	0.1	505.	B400	B400
33	326.5	4691.3	0.0	0.011	0.001	30.5	0.0	0.0	0.	K772	K772
34	319.8	4665.8	0.0	0.576	0.001	30.5	0.0	0.0	0.	B281	B281
35	319.8	4665.8	0.0	1.304	0.000	171.7	4.9	0.8	405.	B281	B281
36	327.6	4685.4	0.0	0.004	0.001	59.5	3.7	0.0	422.	B218	B218
37	321.8	4672.5	0.0	0.002	0.001	70.0	2.1	3.4	455.	B300	B300
38	317.0	4693.9	0.0	0.005	0.001	45.7	3.1	0.0	422.	B369	B369
39	336.3	4695.2	0.0	0.024	0.004	45.7	3.3	0.0	450.	B369	B369
40	333.7	4714.8	0.0	0.003	0.003	30.5	0.0	0.0	0.	F175	F175
41	324.1	4702.4	0.0	0.003	0.003	30.5	0.0	0.0	0.	A980	A980
42	326.8	4707.0	0.0	0.123	0.000	53.4	2.4	4.1	344.	B414	B414
43	322.6	4685.2	0.0	8.960	2.930	64.0	3.1	2.8	672.	A864	A864
44	326.4	4684.0	0.0	1.580	0.730	67.1	3.7	0.8	533.	A974	A974
45	326.2	4683.3	0.0	1.580	0.570	38.1	1.5	3.9	314.	B363	B363
46	326.2	4683.3	0.0	3.610	1.310	78.4	3.4	0.0	561.	B363	B363
47	326.2	4683.3	0.0	3.160	1.150	18.3	0.6	0.0	0.	B363	B363
48	326.2	4683.3	0.0	3.810	1.390	108.5	5.0	0.0	561.	B363	B363
49	322.3	4683.1	0.0	0.007	0.005	30.5	0.0	0.0	0.	A983	A983
50	285.0	4745.0	100.00	0.035	0.001	10.0	0.3	0.3	0.	101	101
51	285.0	4735.0	100.00	0.017	0.000	10.0	0.3	0.3	0.	102	102
52	285.0	4725.0	100.00	0.041	0.001	10.0	0.3	0.3	0.	103	103
53	285.0	4715.0	100.00	0.033	0.001	10.0	0.3	0.3	0.	104	104
54	285.0	4705.0	100.00	0.029	0.001	10.0	0.3	0.3	0.	105	105
55	292.5	4677.5	25.00	0.025	0.002	10.0	0.3	0.3	0.	106	106
56	292.5	4692.5	25.00	0.011	0.001	10.0	0.3	0.3	0.	107	107
57	292.5	4687.5	25.00	0.005	0.001	10.0	0.3	0.3	0.	108	108
58	292.5	4692.5	25.00	0.010	0.002	10.0	0.3	0.3	0.	109	109
59	292.5	4697.5	25.00	0.009	0.001	10.0	0.3	0.3	0.	110	110
60	292.5	4707.5	25.00	0.015	0.000	10.0	0.3	0.3	0.	111	111

(Continued)

TABLE C-1. (Continued)

SOURCE NUMBER	SOURCE LOCATION (KILOMETERS) HORIZONTAL	VERTICAL	SOURCE AREA SQUARE KILOMETERS	ANNUAL SOURCE EMISSION RATE (Tons x 10^3/day) 1956-1960	1975-1976	STACK DATA HT (M)	DIAM (M)	VEL (M/SEC)	TEMP (DEG.K)	ID # S	P
61	292.5	4712.5	25.00	0.014	0.000	10.0	0.3	0.3	0.	112	112
62	292.5	4717.5	25.00	0.014	0.000	10.0	0.3	0.3	0.	113	113
63	295.0	4670.0	100.00	0.034	0.004	10.0	0.3	0.3	0.	114	114
64	295.0	4725.0	100.00	0.076	0.002	10.0	0.3	0.3	0.	115	115
65	295.0	4735.0	100.00	0.015	0.000	10.0	0.3	0.3	0.	116	116
66	295.0	4745.0	100.00	0.014	0.000	10.0	0.3	0.3	0.	117	117
67	302.5	4677.5	25.00	0.033	0.003	10.0	0.3	0.3	0.	118	118
68	302.5	4682.5	25.00	0.010	0.010	10.0	0.3	0.3	0.	119	119
69	302.5	4687.5	25.00	0.061	0.010	10.0	0.3	0.3	0.	120	120
70	302.5	4692.5	25.00	0.056	0.009	10.0	0.3	0.3	0.	121	121
71	302.5	4697.5	25.00	0.056	0.009	10.0	0.3	0.3	0.	122	122
72	302.5	4702.5	25.00	0.043	0.001	10.0	0.3	0.3	0.	123	123
73	302.5	4707.5	25.00	0.046	0.002	10.0	0.3	0.3	0.	124	124
74	302.5	4717.5	25.00	0.046	0.001	10.0	0.3	0.3	0.	125	125
75	302.5	4722.5	25.00	0.049	0.001	10.0	0.3	0.3	0.	126	126
76	302.5	4727.5	25.00	0.016	0.000	10.0	0.3	0.3	0.	127	127
77	305.0	4670.0	100.00	0.050	0.004	10.0	0.3	0.3	0.	128	128
78	305.0	4735.0	100.00	0.105	0.002	10.0	0.3	0.3	0.	129	129
79	305.0	4745.0	100.00	0.042	0.001	10.0	0.3	0.3	0.	130	130
80	307.5	4677.5	25.00	0.015	0.001	10.0	0.3	0.3	0.	131	131
81	307.5	4682.5	25.00	0.091	0.010	10.0	0.3	0.3	0.	132	132
82	307.5	4687.5	25.00	0.211	0.021	10.0	0.3	0.3	0.	133	133
83	307.5	4692.5	25.00	0.074	0.012	10.0	0.3	0.3	0.	134	134
84	307.5	4697.5	25.00	0.081	0.012	10.0	0.3	0.3	0.	135	135
85	307.5	4702.5	25.00	0.161	0.005	10.0	0.3	0.3	0.	136	136
86	307.5	4707.5	25.00	0.037	0.001	10.0	0.3	0.3	0.	137	137
87	307.5	4712.5	25.00	0.029	0.001	10.0	0.3	0.3	0.	138	13
88	307.5	4717.5	25.00	0.030	0.001	10.0	0.3	0.3	0.	139	13

(Continued)

TABLE C-1. (Continued)

SOURCE NUMBER	SOURCE LOCATION (KILOMETERS) HORIZONTAL	VERTICAL	SOURCE AREA SQUARE KILOMETERS	ANNUAL SOURCE EMISSION RATE (Tons x 10^3/day) 1956-1960	1975-1976	STACK DATA HT (M)	DIAM (M)	VEL (M/SEC)	TEMP (DEG.K)	ID # S	P
91	312.5	4662.5	25.00	0.029	0.002	10.0	0.3	0.3	0.	142	142
92	312.5	4667.5	25.00	0.019	0.002	10.0	0.3	0.3	0.	143	143
93	312.5	4672.5	25.00	0.043	0.004	10.0	0.3	0.3	0.	144	144
94	312.5	4677.5	25.00	0.100	0.010	10.0	0.3	0.3	0.	145	145
95	312.5	4682.5	25.00	0.199	0.020	10.0	0.3	0.3	0.	146	146
96	312.5	4687.5	25.00	0.248	0.021	10.0	0.3	0.3	0.	147	147
97	312.5	4692.5	25.00	0.314	0.023	10.0	0.3	0.3	0.	148	148
98	312.5	4697.5	25.00	0.388	0.023	10.0	0.3	0.3	0.	149	149
99	312.5	4702.5	25.00	0.262	0.010	10.0	0.3	0.3	0.	150	150
100	312.5	4707.5	25.00	0.038	0.001	10.0	0.3	0.3	0.	151	151
101	312.5	4712.5	25.00	0.032	0.001	10.0	0.3	0.3	0.	152	152
102	312.5	4717.5	25.00	0.024	0.001	10.0	0.3	0.3	0.	153	153
103	312.5	4722.5	25.00	0.342	0.005	10.0	0.3	0.3	0.	154	154
104	312.5	4727.5	25.00	0.153	0.002	10.0	0.3	0.3	0.	155	155
105	315.0	4735.0	100.00	0.078	0.002	10.0	0.3	0.3	0.	156	156
106	315.0	4745.0	100.00	0.025	0.001	10.0	0.3	0.3	0.	157	157
107	317.5	4662.5	25.00	0.014	0.001	10.0	0.3	0.3	0.	158	158
108	317.5	4667.5	25.00	0.069	0.007	10.0	0.3	0.3	0.	159	159
109	317.5	4672.5	25.00	0.115	0.011	10.0	0.3	0.3	0.	160	160
110	317.5	4677.5	25.00	0.265	0.022	10.0	0.3	0.3	0.	161	161
111	317.5	4682.5	25.00	0.284	0.018	10.0	0.3	0.3	0.	162	162
112	317.5	4687.5	25.00	0.258	0.014	10.0	0.3	0.3	0.	163	163
113	317.5	4692.5	25.00	0.777	0.039	10.0	0.3	0.3	0.	164	164
114	317.5	4697.5	25.00	0.777	0.039	10.0	0.3	0.3	0.	165	165
115	317.5	4702.5	25.00	0.369	0.011	10.0	0.3	0.3	0.	166	166
116	317.5	4707.5	25.00	0.184	0.005	10.0	0.3	0.3	0.	167	167
117	317.5	4712.5	25.00	0.350	0.005	10.0	0.3	0.3	0.	168	168
118	317.5	4722.5	25.00	0.063	0.001	10.0	0.3	0.3	0.	169	169
119	317.5	4727.5	25.00	0.016	0.000	10.0	0.3	0.3	0.	170	170
120	317.5	4657.5	25.00	0.008	0.001	10.0	0.3	0.3	0.	171	171

(Continued)

TABLE C-1. (Continued)

SOURCE NUMBER	SOURCE LOCATION (KILOMETERS) HORIZONTAL	VERTICAL	SOURCE AREA SQUARE KILOMETERS	ANNUAL SOURCE EMISSION RATE (Tons x 10^3/day) 1956-1960	1975-1976	STACK DATA HT (M)	DIAM (M)	VEL (M/SEC)	TEMP (DEG.K)	ID # S	P
121	322.5	4662.5	25.00	0.008	0.001	10.0	0.3	0.3	0.	172	172
122	322.5	4667.5	25.00	0.025	0.002	10.0	0.3	0.3	0.	173	173
123	322.5	4672.5	25.00	0.109	0.009	10.0	0.3	0.3	0.	174	174
124	322.5	4677.5	25.00	0.319	0.020	10.0	0.3	0.3	0.	175	175
125	322.5	4682.5	25.00	0.389	0.021	10.0	0.3	0.3	0.	176	176
126	322.5	4687.5	25.00	0.526	0.028	10.0	0.3	0.3	0.	177	177
127	322.5	4692.5	25.00	0.931	0.047	10.0	0.3	0.3	0.	178	178
128	322.5	4697.5	25.00	0.791	0.040	10.0	0.3	0.3	0.	179	179
129	322.5	4702.5	25.00	0.910	0.014	10.0	0.3	0.3	0.	180	180
130	322.5	4707.5	25.00	0.809	0.010	10.0	0.3	0.3	0.	181	181
131	322.5	4712.5	25.00	0.125	0.003	10.0	0.3	0.3	0.	182	182
132	322.5	4717.5	25.00	0.010	0.000	10.0	0.3	0.3	0.	183	183
133	322.5	4722.5	25.00	0.028	0.001	10.0	0.3	0.3	0.	184	184
134	322.5	4727.5	25.00	0.061	0.001	10.0	0.3	0.3	0.	185	185
135	325.0	4735.0	100.00	0.037	0.001	10.0	0.3	0.3	0.	186	186
136	325.0	4747.0	100.00	0.017	0.000	10.0	0.3	0.3	0.	187	187
137	327.5	4682.5	25.00	0.049	0.002	10.0	0.3	0.3	0.	188	188
138	327.5	4687.5	25.00	0.756	0.038	10.0	0.3	0.3	0.	189	189
139	327.5	4692.5	25.00	1.519	0.076	10.0	0.3	0.3	0.	190	190
140	327.5	4697.5	25.00	0.983	0.047	10.0	0.3	0.3	0.	191	191
141	327.5	4702.5	25.00	1.085	0.014	10.0	0.3	0.3	0.	192	192
142	327.5	4707.5	25.00	0.244	0.006	10.0	0.3	0.3	0.	193	193
143	327.5	4712.5	25.00	0.047	0.002	10.0	0.3	0.3	0.	194	194
144	327.5	4717.5	25.00	0.010	0.000	10.0	0.3	0.3	0.	195	195
145	327.5	4722.5	25.00	0.014	0.000	10.0	0.3	0.3	0.	196	196
146	327.5	4727.5	25.00	0.032	0.001	10.0	0.3	0.3	0.	197	197
147	332.5	4687.5	25.00	0.490	0.025	10.0	0.3	0.3	0.	198	198
148	332.5	4692.5	25.00	0.952	0.048	10.0	0.3	0.3	0.	199	199
149	332.5	4697.5	25.00	0.742	0.035	10.0	0.3	0.3	0.	200	200
150	332.5	4702.5	25.00	0.343	0.012	10.0	0.3	0.3	0.	201	201

(Continued)

TABLE C-1. (Continued)

SOURCE NUMBER	SOURCE LOCATION (KILOMETERS) HORIZONTAL	VERTICAL	SOURCE AREA SQUARE KILOMETERS	ANNUAL SOURCE EMISSION RATE (Tons x 10^3/day) 1956-1960	1975-1976	STACK DATA HT (M)	DIAM (M)	VEL (M/SEC)	TEMP (DEG.K)	ID # S	P
151	332.5	4707.5	25.00	0.108	0.004	10.0	0.3	0.3	0.	202	202
152	332.5	4712.5	25.00	0.013	0.001	10.0	0.3	0.3	0.	203	203
153	332.5	4717.5	25.00	0.015	0.002	10.0	0.3	0.3	0.	204	204
154	332.5	4722.5	25.00	0.014	0.001	10.0	0.3	0.3	0.	205	205
155	332.5	4727.5	25.00	0.014	0.001	10.0	0.3	0.3	0.	206	206
156	345.0	4735.0	100.00	0.016	0.001	10.0	0.3	0.3	0.	207	207
157	335.0	4745.0	100.00	0.022	0.001	10.0	0.3	0.3	0.	208	208
158	337.5	4692.5	25.00	0.651	0.033	10.0	0.3	0.3	0.	209	209
159	337.5	4697.5	25.00	0.217	0.011	10.0	0.3	0.3	0.	210	210
160	337.5	4702.5	25.00	0.350	0.013	10.0	0.3	0.3	0.	211	211
161	337.5	4707.5	25.00	0.106	0.005	10.0	0.3	0.3	0.	212	212
162	337.5	4712.5	25.00	0.019	0.002	10.0	0.3	0.3	0.	213	213
163	337.5	4717.5	25.00	0.008	0.001	10.0	0.3	0.3	0.	214	214
164	340.0	4725.0	100.00	0.018	0.001	10.0	0.3	0.3	0.	215	215
165	342.5	4692.5	25.00	0.200	0.012	10.0	0.3	0.3	0.	216	216
166	342.5	4697.5	25.00	0.454	0.029	10.0	0.3	0.3	0.	217	217
167	342.5	4702.5	25.00	0.376	0.011	10.0	0.3	0.3	0.	218	218
168	342.5	4707.5	25.00	0.213	0.007	10.0	0.3	0.3	0.	219	219
169	342.5	4712.5	25.00	0.036	0.003	10.0	0.3	0.3	0.	220	220
170	342.5	4717.5	25.00	0.020	0.001	10.0	0.3	0.3	0.	221	221
171	345.0	4735.0	25.00	0.013	0.000	10.0	0.3	0.3	0.	222	222
172	347.5	4702.5	25.00	0.031	0.001	10.0	0.3	0.3	0.	223	223
173	347.5	4707.5	25.00	0.020	0.001	10.0	0.3	0.3	0.	224	224
174	347.5	4712.5	25.00	0.047	0.002	10.0	0.3	0.3	0.	225	225
175	347.5	4717.5	25.00	0.095	0.003	10.0	0.3	0.3	0.	226	226
176	350.0	4725.0	100.00	0.020	0.001	10.0	0.3	0.3	0.	227	227
177	352.5	4717.5	25.00	0.015	0.001	10.0	0.3	0.3	0.	228	228
178	355.0	4735.0	100.00	0.027	0.001	10.0	0.3	0.3	0.	229	229
179	355.0	4745.0	100.00	0.015	0.000	10.0	0.3	0.3	0.	230	230
180	295.0	4695.0	100.00	0.022	0.006	53.3	0.3	0.3	0.	P231	P231

(Continued)

TABLE C-1. (Concluded)

SOURCE NUMBER	SOURCE LOCATION (KILOMETERS) HORIZONTAL	VERTICAL	SOURCE AREA SQUARE KILOMETERS	ANNUAL SOURCE EMISSION RATE (Tons x 10^3/day) 1956-1960	1975-1976	STACK DATA HT (M)	DIAM (M)	VEL (M/SEC)	TEMP (DEG.K)	ID # S	P
181	305.0	4695.0	100.00	0.022	0.006	53.3	0.3	0.3	0.	P232	P232
182	315.0	4695.0	100.00	0.022	0.006	53.3	0.3	0.3	0.	P233	P233
183	325.0	4695.0	100.00	0.022	0.006	53.3	0.3	0.3	0.	P234	P234
184	335.0	4695.0	100.00	0.022	0.006	53.3	0.3	0.3	0.	P235	P235
185	295.0	4685.0	100.00	0.022	0.006	53.3	0.3	0.3	0.	P236	P236
186	305.0	4685.0	100.00	0.022	0.006	53.3	0.3	0.3	0.	P237	P237
187	315.0	4685.0	100.00	0.022	0.006	53.3	0.3	0.3	0.	P238	P238
188	325.0	4685.0	100.00	0.022	0.006	53.3	0.3	0.3	0.	P239	P239
189	300.0	4670.0	400.00	0.022	0.006	53.3	0.3	0.3	0.	M240	M240
190	315.0	4675.0	100.00	0.022	0.006	53.3	0.3	0.3	0.	M241	M241
191	313.3	4663.3	178.00	0.022	0.006	53.3	0.3	0.3	0.	P242	P242
192	342.5	4697.5	25.00	0.005	0.002	53.3	0.3	0.3	0.	P243	P243
193	342.5	4692.5	25.00	0.005	0.002	53.3	0.3	0.3	0.	P244	P244
194	322.5	4677.5	25.00	0.005	0.002	53.3	0.3	0.3	0.	P245	P245
195	322.5	4672.5	25.00	0.005	0.002	53.3	0.3	0.3	0.	P246	P246
196	340.0	4710.0	400.00	0.021	0.009	53.3	0.3	0.3	0.	P247	P247
197	315.0	4715.0	900.00	0.022	0.015	53.3	0.3	0.3	0.	P248	P248

TABLE C-2. SOURCES OF AMBIENT NICKEL AND CADMIUM AND THEIR EMISSIONS FOR THE DETROIT METROPOLITAN AREA.

County	Source Category	Establishment Number	Locations, UTM Coordinates * X	Y	Controlled Emissions kg per year Nickel	Cadmium
Wayne	Zinc smelting	A8030	3328	46992	0	2176
	Zinc smelting	B2159	3308	46932	0	1429
	Zinc smelting	B3175	3297	46926	0	480
	Zinc smelting	B3246	3053	46887	0	299
	Cement manufacturing	B3567	3239	46836	278	278
	Incinerator	B2103	3245	46832	422	961
	Incinerator	B2118	3215	46726	54	123
	Steel production	A7809	3240	46795	97	973
	Steel production	A8640	3226	46852	56	555
	Coal combustion	A8645	3025	46935	44	73
	Coal combustion	B2185	3276	46854	86	143
	Coal combustion	B2800	3227	46762	36	59
	Coal combustion	B2811	3198	46658	471	782
	Coal combustion	B2812	3387	46911	34	57
	Coal combustion	B3011	3302	46906	87	144
	Coal combustion	B3165	3067	46845	57	95
	Coal combustion	B3683	3260	46831	138	229
	Coal combustion	B4009	3222	46733	1454	2414
	Coal combustion	B4073	3012	46832	42	70
	Coal combustion	B4277	3278	46936	79	131
	Coal combustion	M2680	3294	46900	41	67
Macomb	Coal combustion	A3567	3319	47166	78	131
	Coal combustion	A3568	3318	47255	69	115
	Coal combustion	B1801	3329	47134	43	71
	Coal combustion	B2763	3326	47072	42	70
	Coal combustion	B2767	3322	47021	317	526
Oakland	Coal combustion	A5260	2915	47086	40	66
	Coal combustion	B4030	3148	47207	61	101

* In 100-meter units.

(continued)

TABLE C-2. (Concluded)

County	Source Category	Establishment Number	Locations, UTM Coordinates * X	Y	Controlled Emissions kg per year Nickel	Cadmium
Oakland	Coal combustion	B4033	3126	47214	34	57
	Coal combustion	B4047	3115	47255	208	345
Wayne	Oil combustion	A6928	3318	46895	95	4.7
	Oil combustion	A9831	3223	46831	629	31.4
	Oil combustion	B2137	2999	46940	55	2.8
	Oil combustion	B2798	3267	46847	139	40.6
	Oil combustion	B3680	3198	46666	112	6.9
	Oil combustion	B4275	3265	46857	112	5.6
Macomb	Oil combustion	B1798	3323	47035	149	7.4
	Oil combustion	B4049	3323	47086	142	7.1
Oakland	Oil combustion	A5262	2804	47162	60	3.0

* In 100-meter units.

Appendix D

TABLE D-1. AMBIENT BaP CONCENTRATIONS AS REPORTED BY SAWICKI ET AL. (18) FOR DETROIT*

Month and Year	BaP Concentrations in Nanograms/Cubic Meter
July 1958	6.0
August 1958	4.1
September 1958	--
October 1958	18.0
November 1958	19.0
December 1958	20.0
January 1959	28.0
February 1959	31.0
March 1959	16.0
April 1959	12.0
May 1959	7.4
June 1959	3.4
11-month average	15.0

* Site location shown in Figure 9.

TABLE D-2. ANNUAL AVERAGE AMBIENT BaP CONCENTRATIONS AT NASN SITES IN THE DETROIT METROPOLITAN STUDY AREA, ng/m^3

Year	Detroit*	Dearborn**	Trenton**	Flint**
1966	4.7			
1967	5.4			1.4
1968	5.1		1.4	0.8
1969	3.9		1.6	1.7
1970	2.6		0.2	0.5
1971	1.4			
1972	1.9	0.6		
1973	1.0	1.0		
1974	--	1.7		
1975	1.0	--		

* Site locations are shown in Figure 9.

† Sites not shown in Figure 9; their UTM x and y coordinates are:

Dearborn:	320.8	4687.5
Trenton:	320.0	4667.4
Flint:	281.1	4765.6

TABLE D-3. AMBIENT CONCENTRATIONS OF BaP AS REPORTED BY INTERNATIONAL JOINT COMMISSION STUDY IN ng/m^3

	Site Number*		
Date	401	406	409
December 1967	--	5.9	2.1
January 1968	2.1	6.1	1.5
February 1968	1.7	3.4	1.4
March 1968	1.3	14.9	1.7
April 1968	7.2	6.1	0.8
May 1968	1.0	3.4	0.9
June 1968	0.9	4.3	1.0
July 1968	1.0	2.0	1.0
August 1968	0.7	2.8	0.7
September 1968	0.8	12.0	0.7
October 1968	1.1	16.2	0.6
November 1968	1.1	6.7	1.0
Average	1.6	7.0	1.1

* Site locations are shown in Figure 9.

TABLE D-4. AMBIENT BaP CONCENTRATIONS MEASURED AT WAYNE COUNTY MONITORING SITES IN ng/m^3 (16)

Year	Months	Site Number* 02	04	05	06	08	011
1971	Jan-Mar	4.15	3.38	6.98	4.54	2.26	1.59
	Apr-Jun	2.08	1.89	5.36	2.62	2.04	1.19
	Jul-Sep	1.77	2.12	7.05	2.79	2.79	0.91
	Oct-Dec	4.01	4.50	17.90	2.47	2.47	1.53
Annual Average		3.0	2.97	9.32	3.62	2.39	1.31
1972	Jan-Mar	3.89	4.22	6.53	3.14	2.42	1.79
	Apr-Jun	1.84	1.97	3.18	1.02	1.57	0.90
	Jul-Sep	2.52	4.91	8.76	5.21	4.80	1.37
	Oct-Dec	1.53	1.47	5.33	1.09	1.45	1.22
Annual Average		2.45	3.14	5.95	2.62	2.56	1.32
1973	Jan-Mar	3.05	5.13	18.4	4.43	3.50	2.47
	Apr-Jun	3.79	4.62	13.5	3.83	2.91	1.85
	Jul-Sep	2.08	3.61	7.15	2.00	2.26	1.72
	Oct-Dec	3.17	3.26	8.07	2.23	2.11	1.96
Annual Average		3.02	4.16	11.78	3.12	2.70	2.00
1974	Jan-Mar	1.30	1.81	6.20	0.37	0.65	0.21
	Apr-Jun	1.58	2.13	9.16	0.20	0.36	0.59
	Jul-Sep	1.80	1.39	4.04	0.45	0.36	0.39
	Oct-Dec	1.17	1.45	23.92	1.04	0.39	0.15
Annual Average		1.46	1.70	10.83	0.52	0.44	0.34
1975	Jan-Mar	4.30	4.85	10.63	1.41	2.15	1.16
	Apr-Jun	4.97	6.74	20.93	1.73	2.03	0.75
	Jul-Sep	2.30	3.30	11.03	1.52	1.59	0.48
	Oct-Dec	2.15	4.51	16.27	1.21	4.40	0.54
Annual Average		3.43	4.85	14.72	1.47	2.54	0.73
1976	Jan-Mar	1.20	2.78	6.20	0.49	0.66	0.34
	Apr-Jun	0.94	1.84	7.75	1.61	1.02	0.61
	Jul-Sep	0.86	1.94	5.21	0.44	1.10	0.43
	Oct-Dec	2.05	2.67	5.62	0.86	1.78	0.68
Annual Average		1.26	2.31	6.20	0.85	1.14	0.52

* Site locations are shown in Figure 9.

TABLE D-5. AMBIENT CONCENTRATIONS OF NICKEL IN THE DETROIT METROPOLITAN STUDY AREA IN ug/m^3

Year & Quarter	Wayne County Sites*							NASN Sites†				
	01	04	05	06	012	32	34	1	2	3	4	5
1971												
1st	.013	.054	.060	.008	.015	.122	.045					
2nd	.007	.026	.023	.000	.008	.013	.027					
3rd	.007	.014	.040	.000	.000	.090	.027					
4th	.006	.014	.013	.014	.000	.012	.026					
Average	.008	.027	.034	.005	.006	.059	.031					
1972												
1st	.031	.066	.086	.018	.039	.256	.078					
2nd	.078	.078	.128	.018	.026	.118	.031			.000		.000
3rd	.101	.087	.112	.043	.091	.082	.044			.000		.000
4th	.092	.078	.138	.064	.072	.065	.062			.000		.000
Average	.075	.077	.116	.036	.057	.130	.054					.000
1973												
1st	.028	.048	.039	.022	.015	.015	.024	.000		.000		.000
2nd	.028	.041	.039	.010	.010	.030	.027	.000		.000		.000
3rd	.023	.025	.035	.013	.013	.024	.018	.015		.011		.000
4th	.020	.036	.029	.015	.010	.025	.063					
Average	.025	.037	.035	.015	.012	.023	.033					
1974												
1st	.041	.051	.069	.026	.029	.056	.061	.000				
2nd	.046	.045	.053	.037	.037	.051	.066	.000				.000
3rd	.057	.054	.057	.037	.024	.038	.037	.000	.000			.000
4th	.038	.058	.057	.043	.037	.062	.054	.000	.000	.000		
Average	.045	.052	.059	.036	.032	.052	.054					
1975												
1st	.016	.017	.035	.016	.026	.028	.024	.019	.016		.009	
2nd	.016	.017	.017	.024	.008	.016	.016		.011			
3rd	.017	.018	.017	.007	.005	.017	.016	.012	.000			
4th	.017	.017	.017	.016	.004	.017	.007	.013	.012		.000	
Average	.016	.017	.035	.016	.026	.019	.016	.015	.013			
1976												
1st	.012	.023			.016	.040	.034					
2nd	.019	.025	.033	.021	.008	.018	.013					
3rd	.012	.025	.022	.016	.017	.017	.016					
4th	.016	.016	.015	.016	.016	.025	.024					
Average	.015	.022	.023	.018	.014	.025	.022					

* Site locations shown in Figure 25.

† NASN sites and their x and y UTM coordinates are:

1. Dearborn 320.8 4687.5
2. Detroit 329.8 4691.4
3. Flint 281.1 4765.6
4. Flint 281.0 4765.3
5. Trenton 320.0 4667.4

TABLE D-6. AMBIENT CONCENTRATIONS OF CADMIUM IN THE DETROIT METROPOLITAN AREA IN ug/m^3

Year & Quarter	Wayne County Sites*							NASN Sites†				
	01	04	05	06	012	32	34	1	2	3	4	5
1971												
1st	.007	.004	.006	.006	.003	.027	.007		.000	.000		.000
2nd	.006	.005	.006	.003	.006	.014	.012	.000	.000	.000		.000
3rd	.007	.006	.011	.003	.003	.002	.006	.000	.000	.000		.000
4th	.005	.005	.012	.005	.004	.018	.003		.000	.000		.000
Average	.006	.005	.009	.004	.004	.015	.007					
1972												
1st	.108	.004	.008	.002	.005	.010	.005			.000		.000
2nd	.006	.006	.005	.006	.005	.010	.004			.000		.000
3rd	.003	.003	.004	.002	.002	.008	.003			.000		.000
4th	.006	.004	.006	.002	.003	.004	.005					.000
Average	.031	.004	.006	.003	.004	.008	.004					
1973												
1st	.004	.005	.005	.003	.007	.009	.003	.000		.000		.000
2nd	.003	.004	.005	.003	.003	.009	.003	.000		.000		.000
3rd	.004	.004	.005	.003	.003	.011	.003	.000		.000		.000
4th	.004	.005	.007	.003	.003	.009	.006					
Average	.004	.004	.005	.003	.004	.009	.004					
1974												
1st	.004	.004	.007	.004	.003	.005	.004	.000				
2nd	.005	.004	.005	.003	.003	.006	.003	.000				.000
3rd	.004	.005	.007	.004	.004	.004	.005	.000	.000			.000
4th	.005	.006	.006	.006	.004	.007	.005	.000	.000	.000		
Average	.004	.005	.006	.004	.003	.005	.004					
1975												
1st	.002	.003	.004	.002	.003	.005	.002	.008	.000	.000		
2nd	.003	.002	.004	.002	.003	.005	.002		.005			
3rd	.002	.002	.005	.004	.003	.004	.002	.000	.000			
4th	.002	.003	.004	.002	.002	.004	.002	.006	.005	.000		
Average	.002	.002	.004	.002	.003	.004	.002	.005	.002	.000		
1976												
1st	.003	.002			.001	.002	.002					
2nd	.004	.003	.002	.002	.000	.004	.003					
3rd	.004	.002	.005	.002	.001	.005	.007					
4th	.002	.002	.004	.002	.001	.003	.005					
Average	.003	.002	.004	.002	.001	.003	.004					

* Site Locations shown in Figure 30.

† NASN sites and their x and y UTM coordinates are:

1.	Dearborn	320.8	4687.5
2.	Detroit	329.8	4691.4
3.	Flint	281.1	4765.6
4.	Flint	281.0	4765.3
5.	Trenton	320.0	4667.4

TABLE E-1. 1975-76 METEOROLOGICAL INPUT DATA FOR AQDM

MIXING DEPTH = 1350. METERS
AMBIENT TEMPERATURE = 293. DEGREES,KELVIN
AMBIENT PRESSURE = 1017. MILLIBARS

STABILITY CLASS 1

	WINDSPEED CLASS					
WIND DIRECTION	1	2	3	4	5	6
N	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
NNE	0.0006	0.0000	0.0000	0.0000	0.0000	0.0000
NE	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
ENE	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
E	0.0002	0.0002	0.0000	0.0000	0.0000	0.0000
ESE	0.0002	0.0002	0.0000	0.0000	0.0000	0.0000
SE	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
SSE	0.0004	0.0000	0.0000	0.0000	0.0000	0.0000
S	0.0002	0.0000	0.0000	0.0000	0.0000	0.0000
SSW	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
SW	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
WSW	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000
W	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000
WNW	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
NW	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
NNW	0.0002	0.0003	0.0000	0.0000	0.0000	0.0000

(Continued)

TABLE E-1. (Continued)

STABILITY CLASS 2	WINDSPEED CLASS					
WIND DIRECTION	1	2	3	4	5	6
N	0.0007	0.0009	0.0007	0.0000	0.0000	0.0000
NNE	0.0009	0.0009	0.0010	0.0000	0.0000	0.0000
NE	0.0003	0.0010	0.0003	0.0000	0.0000	0.0000
ENE	0.0005	0.0007	0.0015	0.0000	0.0000	0.0000
E	0.0002	0.0005	0.0010	0.0000	0.0000	0.0000
ESE	0.0002	0.0015	0.0014	0.0000	0.0000	0.0000
SE	0.0002	0.0003	0.0010	0.0000	0.0000	0.0000
SSE	0.0005	0.0007	0.0000	0.0000	0.0000	0.0000
S	0.0006	0.0017	0.0009	0.0000	0.0000	0.0000
SSW	0.0000	0.0003	0.0000	0.0000	0.0000	0.0000
SW	0.0003	0.0007	0.0003	0.0000	0.0000	0.0000
WSW	0.0000	0.0000	0.0003	0.0000	0.0000	0.0000
W	0.0005	0.0009	0.0005	0.0000	0.0000	0.0000
WNW	0.0002	0.0003	0.0002	0.0000	0.0000	0.0000
NW	0.0001	0.0010	0.0007	0.0000	0.0000	0.0000
NNW	0.0008	0.0005	0.0002	0.0000	0.0000	0.0000

(Continued)

TABLE E-1. (Continued)

STABILITY CLASS 5

WIND DIRECTION	WINDSPEED CLASS 1	2	3	4	5	6
N	0.0008	0.0007	0.0036	0.0002	0.0000	0.0000
NNE	0.0000	0.0007	0.0017	0.0002	0.0000	0.0000
NE	0.0002	0.0007	0.0017	0.0010	0.0000	0.0000
ENE	0.0001	0.0017	0.0038	0.0002	0.0000	0.0000
E	0.0001	0.0009	0.0053	0.0012	0.0000	0.0000
ESE	0.0000	0.0005	0.0043	0.0000	0.0000	0.0000
SE	0.0001	0.0009	0.0027	0.0002	0.0000	0.0000
SSE	0.0001	0.0012	0.0015	0.0003	0.0000	0.0000
S	0.0001	0.0010	0.0051	0.0015	0.0002	0.0000
SSW	0.0000	0.0007	0.0043	0.0005	0.0000	0.0002
SW	0.0001	0.0015	0.0050	0.0009	0.0005	0.0000
WSW	0.0002	0.0009	0.0019	0.0015	0.0000	0.0000
W	0.0003	0.0019	0.0089	0.0019	0.0000	0.0000
WNW	0.0002	0.0010	0.0026	0.0007	0.0000	0.0000
NW	0.0000	0.0007	0.0039	0.0009	0.0000	0.0000
NNW	0.0003	0.0015	0.0038	0.0007	0.0000	0.0000

(Continued)

TABLE E-1. (Continued)

STABILITY CLASS 4

WIND DIRECTION	WINDSPEED CLASS 1	2	3	4	5	6
N	0.0008	0.0055	0.0192	0.0161	0.0024	0.0002
NNE	0.0002	0.0029	0.0079	0.0087	0.0007	0.0000
NE	0.0006	0.0026	0.0070	0.0087	0.0007	0.0002
ENE	0.0006	0.0036	0.0105	0.0096	0.0005	0.0000
E	0.0006	0.0038	0.0149	0.0122	0.0005	0.0000
ESE	0.0008	0.0031	0.0149	0.0082	0.0002	0.0000
SE	0.0002	0.0022	0.0116	0.0063	0.0002	0.0002
SSE	0.0003	0.0021	0.0113	0.0058	0.0003	0.0002
S	0.0007	0.0027	0.0229	0.0347	0.0060	0.0003
SSW	0.0004	0.0024	0.0147	0.0322	0.0048	0.0021
SW	0.0004	0.0005	0.0137	0.0430	0.0092	0.0022
WSW	0.0001	0.0019	0.0137	0.0315	0.0075	0.0015
W	0.0005	0.0050	0.0346	0.0515	0.0063	0.0017
WNW	0.0002	0.0034	0.0132	0.0193	0.0010	0.0000
NW	0.0006	0.0039	0.0135	0.0190	0.0022	0.0000
NNW	0.0006	0.0027	0.0068	0.0159	0.0017	0.0000

(Continued)

TABLE E-1. (Continued)

STABILITY CLASS 5

WIND DIRECTION	WINDSPEED CLASS 1	2	3	4	5	6
N	0.0000	0.0027	0.0060	0.0000	0.0000	0.0000
NNE	0.0000	0.0012	0.0022	0.0000	0.0000	0.0000
NE	0.0000	0.0009	0.0027	0.0000	0.0000	0.0000
ENE	0.0000	0.0015	0.0034	0.0000	0.0000	0.0000
E	0.0000	0.0012	0.0026	0.0000	0.0000	0.0000
ESE	0.0000	0.0017	0.0038	0.0000	0.0000	0.0000
SE	0.0000	0.0024	0.0026	0.0000	0.0000	0.0000
SSE	0.0000	0.0015	0.0058	0.0000	0.0000	0.0000
S	0.0000	0.0034	0.0094	0.0000	0.0000	0.0000
SSW	0.0000	0.0005	0.0060	0.0000	0.0000	0.0000
SW	0.0000	0.0015	0.0087	0.0000	0.0000	0.0000
WSW	0.0000	0.0005	0.0062	0.0000	0.0000	0.0000
W	0.0000	0.0031	0.0190	0.0000	0.0000	0.0000
WNW	0.0000	0.0021	0.0067	0.0000	0.0000	0.0000
NW	0.0000	0.0012	0.0051	0.0000	0.0000	0.0000
NNW	0.0000	0.0005	0.0043	0.0000	0.0000	0.0000

(Continued)

TABLE E-1. (Concluded)

STABILITY CLASS 6

WIND DIRECTION	WINDSPEED CLASS 1	2	3	4	5	6
N	0.0043	0.0055	0.0000	0.0000	0.0000	0.0000
NNE	0.0017	0.0015	0.0000	0.0000	0.0000	0.0000
NE	0.0003	0.0019	0.0000	0.0000	0.0000	0.0000
ENE	0.0014	0.0031	0.0000	0.0000	0.0000	0.0000
E	0.0011	0.0015	0.0000	0.0000	0.0000	0.0000
ESE	0.0014	0.0029	0.0000	0.0000	0.0000	0.0000
SE	0.0018	0.0029	0.0000	0.0000	0.0000	0.0000
SSE	0.0011	0.0046	0.0000	0.0000	0.0000	0.0000
S	0.0041	0.0091	0.0000	0.0000	0.0000	0.0000
SSW	0.0011	0.0024	0.0000	0.0000	0.0000	0.0000
SW	0.0007	0.0017	0.0000	0.0000	0.0000	0.0000
WSW	0.0014	0.0022	0.0000	0.0000	0.0000	0.0000
W	0.0039	0.0122	0.0000	0.0000	0.0000	0.0000
WNW	0.0016	0.0060	0.0000	0.0000	0.0000	0.0000
NW	0.0016	0.0039	0.0000	0.0000	0.0000	0.0000
NNW	0.0022	0.0033	0.0000	0.0000	0.0000	0.0000

TABLE E-2. 1956-60 METEOROLOGICAL INPUT DATA FOR AQDM

MIXING DEPTH = 1300. METERS
AMBIENT TEMPERATURE = 283. DEGREES,KELVIN
AMBIENT PRESSURE = 1017. MILLIBARS

STABILITY CLASS 1

	WINDSPEED CLASS					
WIND DIRECTION	1	2	3	4	5	6
N	0.0001	0.0003	0.0000	0.0000	0.0000	0.0000
NNE	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
NE	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000
ENE	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000
E	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
ESE	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000
SE	0.0001	0.0002	0.0000	0.0000	0.0000	0.0000
SSE	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
S	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000
SSW	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
SW	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
WSW	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000
WNW	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000
NW	0.0001	0.0002	0.0000	0.0000	0.0000	0.0000
NNW	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000

(Continued)

TABLE E-2. (Continued)

STABILITY CLASS 2	WINDSPEED CLASS					
WIND DIRECTION	1	2	3	4	5	6
N	0.0010	0.0012	0.0009	0.0000	0.0000	0.0000
NNE	0.0005	0.0007	0.0007	0.0000	0.0000	0.0000
NE	0.0005	0.0008	0.0008	0.0000	0.0000	0.0000
ENE	0.0003	0.0007	0.0010	0.0000	0.0000	0.0000
E	0.0006	0.0014	0.0015	0.0000	0.0000	0.0000
ESE	0.0003	0.0010	0.0016	0.0000	0.0000	0.0000
SE	0.0005	0.0010	0.0017	0.0000	0.0000	0.0000
SSE	0.0003	0.0005	0.0005	0.0000	0.0000	0.0000
S	0.0005	0.0008	0.0011	0.0000	0.0000	0.0000
SSW	0.0001	0.0005	0.0008	0.0000	0.0000	0.0000
SW	0.0002	0.0004	0.0005	0.0000	0.0000	0.0000
WSW	0.0001	0.0002	0.0005	0.0000	0.0000	0.0000
W	0.0005	0.0006	0.0006	0.0000	0.0000	0.0000
WNW	0.0002	0.0006	0.0008	0.0000	0.0000	0.0000
NW	0.0007	0.0011	0.0008	0.0000	0.0000	0.0000
NNW	0.0004	0.0007	0.0006	0.0000	0.0000	0.0000

(Continued)

TABLE E-2. (Continued)

STABILITY CLASS 3	WINDSPEED CLASS					
WIND DIRECTION	1	2	3	4	5	6
N	0.0008	0.0020	0.0045	0.0010	0.0000	0.0000
NNE	0.0005	0.0013	0.0023	0.0005	0.0000	0.0000
NE	0.0003	0.0011	0.0019	0.0003	0.0000	0.0000
ENE	0.0002	0.0009	0.0028	0.0006	0.0000	0.0000
E	0.0004	0.0010	0.0047	0.0007	0.0000	0.0000
ESE	0.0003	0.0007	0.0043	0.0005	0.0000	0.0000
SE	0.0002	0.0016	0.0042	0.0003	0.0000	0.0000
SSE	0.0002	0.0009	0.0031	0.0002	0.0000	0.0000
S	0.0003	0.0014	0.0070	0.0013	0.0000	0.0000
SSW	0.0001	0.0006	0.0045	0.0009	0.0000	0.0000
SW	0.0002	0.0009	0.0038	0.0013	0.0002	0.0000
WSW	0.0001	0.0004	0.0029	0.0008	0.0001	0.0000
W	0.0002	0.0010	0.0043	0.0013	0.0001	0.0001
WNW	0.0001	0.0006	0.0034	0.0012	0.0002	0.0002
NW	0.0003	0.0012	0.0041	0.0010	0.0003	0.0000
NNW	0.0002	0.0008	0.0026	0.0007	0.0000	0.0000

(Continued)

TABLE E-2. (Continued)

STABILITY CLASS 4

WIND DIRECTION	WINDSPEED CLASS 1	2	3	4	5	6
N	0.0026	0.0090	0.0224	0.0235	0.0033	0.0003
NNE	0.0012	0.0053	0.0108	0.0089	0.0005	0.0001
NE	0.0014	0.0045	0.0108	0.0090	0.0002	0.0000
ENE	0.0007	0.0042	0.0111	0.0075	0.0002	0.0000
E	0.0023	0.0071	0.0144	0.0066	0.0006	0.0000
ESE	0.0005	0.0034	0.0083	0.0044	0.0002	0.0000
SE	0.0010	0.0048	0.0106	0.0042	0.0002	0.0000
SSE	0.0004	0.0031	0.0088	0.0034	0.0003	0.0000
S	0.0010	0.0068	0.0264	0.0155	0.0011	0.0001
SSW	0.0007	0.0019	0.0142	0.0172	0.0013	0.0001
SW	0.0004	0.0028	0.0200	0.0398	0.0078	0.0022
WSW	0.0002	0.0012	0.0115	0.0229	0.0054	0.0011
W	0.0007	0.0030	0.0147	0.0321	0.0070	0.0033
WNW	0.0003	0.0017	0.0105	0.0319	0.0106	0.0037
NW	0.0010	0.0031	0.0133	0.0301	0.0085	0.0019
NNW	0.0005	0.0020	0.0075	0.0171	0.0037	0.0004

(Continued)

TABLE E-2. (Continued)

STABILITY CLASS 5

WIND DIRECTION	WINDSPEED CLASS 1	2	3	4	5	6
N	0.0000	0.0051	0.0099	0.0000	0.0000	0.0000
NNE	0.0000	0.0021	0.0037	0.0000	0.0000	0.0000
NE	0.0000	0.0023	0.0024	0.0000	0.0000	0.0000
ENE	0.0000	0.0019	0.0029	0.0000	0.0000	0.0000
E	0.0000	0.0034	0.0029	0.0000	0.0000	0.0000
ESE	0.0000	0.0018	0.0015	0.0000	0.0000	0.0000
SE	0.0000	0.0037	0.0031	0.0000	0.0000	0.0000
SSE	0.0000	0.0027	0.0020	0.0000	0.0000	0.0000
S	0.0000	0.0069	0.0099	0.0000	0.0000	0.0000
SSW	0.0000	0.0016	0.0045	0.0000	0.0000	0.0000
SW	0.0000	0.0019	0.0098	0.0000	0.0000	0.0000
WSW	0.0000	0.0009	0.0049	0.0000	0.0000	0.0000
W	0.0000	0.0014	0.0112	0.0000	0.0000	0.0000
WNW	0.0000	0.0005	0.0071	0.0000	0.0000	0.0000
NW	0.0000	0.0012	0.0087	0.0000	0.0000	0.0000
NNW	0.0000	0.0008	0.0034	0.0000	0.0000	0.0000

(Continued)

TABLE E-2. (Concluded)

STABILITY CLASS 6

WIND DIRECTION	WINDSPEED CLASS 1	2	3	4	5	6
N	0.0089	0.0108	0.0000	0.0000	0.0000	0.0000
NNE	0.0029	0.0042	0.0000	0.0000	0.0000	0.0000
NE	0.0048	0.0040	0.0000	0.0000	0.0000	0.0000
ENE	0.0016	0.0021	0.0000	0.0000	0.0000	0.0000
E	0.0051	0.0041	0.0000	0.0000	0.0000	0.0000
ESE	0.0014	0.0019	0.0000	0.0000	0.0000	0.0000
SE	0.0040	0.0044	0.0000	0.0000	0.0000	0.0000
SSE	0.0016	0.0026	0.0000	0.0000	0.0000	0.0000
S	0.0042	0.0102	0.0000	0.0000	0.0000	0.0000
SSW	0.0009	0.0021	0.0000	0.0000	0.0000	0.0000
SW	0.0018	0.0038	0.0000	0.0000	0.0000	0.0000
WSW	0.0005	0.0021	0.0000	0.0000	0.0000	0.0000
W	0.0026	0.0047	0.0000	0.0000	0.0000	0.0000
WNW	0.0009	0.0021	0.0000	0.0000	0.0000	0.0000
NW	0.0035	0.0050	0.0000	0.0000	0.0000	0.0000
NNW	0.0018	0.0020	0.0000	0.0000	0.0000	0.0000

TABLE E-3. 1958 and 1959 METEOROLOGICAL INPUT DATA FOR AQDM
(FOR ESTIMATION OF 1958-59 BAP CONCENTRATION AT THE NASN SITE)

MIXING DEPTH = 1300. METERS
AMBIENT TEMPERATURE = 283. DEGREES,KELVIN
AMBIENT PRESSURE = 1017. MILLIBARS

STABILITY CLASS 1

	WINDSPEED CLASS					
WIND DIRECTION	1	2	3	4	5	6
N	0.0001	0.0003	0.0000	0.0000	0.0000	0.0000
NNE	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000
NE	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000
ENE	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000
E	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000
ESE	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000
SE	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000
SSE	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000
S	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
SSW	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000
SW	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000
WSW	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000
WNW	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
NW	0.0001	0.0002	0.0000	0.0000	0.0000	0.0000
NNW	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000

(Continued)

TABLE E-3. (Continued)

STABILITY CLASS 2

WIND DIRECTION	WINDSPEED CLASS 1	2	3	4	5	6
N	0.0009	0.0013	0.0012	0.0000	0.0000	0.0000
NNE	0.0004	0.0009	0.0009	0.0000	0.0000	0.0000
NE	0.0005	0.0008	0.0008	0.0000	0.0000	0.0000
ENE	0.0001	0.0005	0.0008	0.0000	0.0000	0.0000
E	0.0006	0.0015	0.0015	0.0000	0.0000	0.0000
ESE	0.0003	0.0007	0.0013	0.0000	0.0000	0.0000
SE	0.0002	0.0009	0.0021	0.0000	0.0000	0.0000
SSE	0.0003	0.0004	0.0006	0.0000	0.0000	0.0000
S	0.0002	0.0005	0.0011	0.0000	0.0000	0.0000
SSW	0.0000	0.0005	0.0009	0.0000	0.0000	0.0000
SW	0.0000	0.0003	0.0006	0.0000	0.0000	0.0000
WSW	0.0002	0.0002	0.0006	0.0000	0.0000	0.0000
W	0.0003	0.0003	0.0005	0.0000	0.0000	0.0000
WNW	0.0003	0.0005	0.0007	0.0000	0.0000	0.0000
NW	0.0005	0.0011	0.0007	0.0000	0.0000	0.0000
NNW	0.0003	0.0007	0.0006	0.0000	0.0000	0.0000

(Continued)

TABLE E-3. (Continued)

STABILITY CLASS 3	WINDSPEED CLASS					
WIND DIRECTION	1	2	3	4	5	6
N	0.0007	0.0018	0.0047	0.0011	0.0001	0.0000
NNE	0.0000	0.0011	0.0030	0.0003	0.0000	0.0000
NE	0.0002	0.0011	0.0018	0.0004	0.0000	0.0000
ENE	0.0002	0.0007	0.0015	0.0003	0.0000	0.0000
E	0.0006	0.0008	0.0036	0.0006	0.0000	0.0000
ESE	0.0004	0.0007	0.0041	0.0005	0.0000	0.0000
SE	0.0002	0.0014	0.0049	0.0003	0.0000	0.0000
SSE	0.0002	0.0008	0.0038	0.0005	0.0000	0.0000
S	0.0002	0.0010	0.0072	0.0014	0.0000	0.0000
SSW	0.0001	0.0005	0.0051	0.0013	0.0000	0.0000
SW	0.0002	0.0006	0.0041	0.0017	0.0003	0.0000
WSW	0.0001	0.0004	0.0027	0.0007	0.0001	0.0000
W	0.0003	0.0009	0.0032	0.0013	0.0000	0.0001
WNW	0.0001	0.0006	0.0034	0.0009	0.0004	0.0002
NW	0.0002	0.0011	0.0032	0.0010	0.0006	0.0001
NNW	0.0001	0.0005	0.0028	0.0007	0.0000	0.0000

(Continued)

TABLE E-3. (Continued)

STABILITY CLASS 4						
	WINDSPEED CLASS					
WIND DIRECTION	1	2	3	4	5	6
N	0.0025	0.0075	0.0215	0.0243	0.0039	0.0003
NNE	0.0013	0.0047	0.0127	0.0121	0.0008	0.0002
NE	0.0010	0.0034	0.0135	0.0118	0.0002	0.0000
ENE	0.0005	0.0028	0.0120	0.0084	0.0002	0.0000
E	0.0016	0.0047	0.0118	0.0076	0.0005	0.0000
ESE	0.0006	0.0026	0.0082	0.0046	0.0002	0.0000
SE	0.0009	0.0029	0.0111	0.0045	0.0002	0.0000
SSE	0.0004	0.0029	0.0080	0.0020	0.0000	0.0000
S	0.0010	0.0087	0.0275	0.0140	0.0005	0.0000
SSW	0.0002	0.0019	0.0170	0.0197	0.0007	0.0002
SW	0.0006	0.0037	0.0187	0.0425	0.0071	0.0018
WSW	0.0002	0.0012	0.0119	0.0264	0.0050	0.0010
W	0.0006	0.0026	0.0160	0.0350	0.0072	0.0046
WNW	0.0003	0.0015	0.0113	0.0299	0.0105	0.0029
NW	0.0007	0.0022	0.0139	0.0337	0.0096	0.0028
NNW	0.0002	0.0017	0.0080	0.0200	0.0047	0.0002

(Continued)

TABLE E-3. (Continued)

STABILITY CLASS 5

WIND DIRECTION	WINDSPEED CLASS 1	2	3	4	5	6
N	0.0000	0.0047	0.0112	0.0000	0.0000	0.0000
NNE	0.0000	0.0017	0.0036	0.0000	0.0000	0.0000
NE	0.0000	0.0020	0.0022	0.0000	0.0000	0.0000
ENE	0.0000	0.0016	0.0031	0.0000	0.0000	0.0000
E	0.0000	0.0030	0.0024	0.0000	0.0000	0.0000
ESE	0.0000	0.0019	0.0006	0.0000	0.0000	0.0000
SE	0.0000	0.0028	0.0039	0.0000	0.0000	0.0000
SSE	0.0000	0.0019	0.0019	0.0000	0.0000	0.0000
S	0.0000	0.0063	0.0106	0.0000	0.0000	0.0000
SSW	0.0000	0.0019	0.0061	0.0000	0.0000	0.0000
SW	0.0000	0.0022	0.0111	0.0000	0.0000	0.0000
WSW	0.0000	0.0010	0.0051	0.0000	0.0000	0.0000
W	0.0000	0.0009	0.0108	0.0000	0.0000	0.0000
WNW	0.0000	0.0005	0.0066	0.0000	0.0000	0.0000
NW	0.0000	0.0007	0.0078	0.0000	0.0000	0.0000
NNW	0.0000	0.0006	0.0030	0.0000	0.0000	0.0000

(Continued)

TABLE E-3. (Concluded)

STABILITY CLASS 6

WIND DIRECTION	WINDSPEED CLASS 1	2	3	4	5	6
N	0.0072	0.0095	0.0000	0.0000	0.0000	0.0000
NNE	0.0024	0.0049	0.0000	0.0000	0.0000	0.0000
NE	0.0031	0.0039	0.0000	0.0000	0.0000	0.0000
ENE	0.0008	0.0016	0.0000	0.0000	0.0000	0.0000
E	0.0038	0.0035	0.0000	0.0000	0.0000	0.0000
ESE	0.0007	0.0017	0.0000	0.0000	0.0000	0.0000
SE	0.0028	0.0041	0.0000	0.0000	0.0000	0.0000
SSE	0.0008	0.0024	0.0000	0.0000	0.0000	0.0000
S	0.0041	0.0106	0.0000	0.0000	0.0000	0.0000
SSW	0.0006	0.0023	0.0000	0.0000	0.0000	0.0000
SW	0.0017	0.0044	0.0000	0.0000	0.0000	0.0000
WSW	0.0003	0.0015	0.0000	0.0000	0.0000	0.0000
W	0.0033	0.0047	0.0000	0.0000	0.0000	0.0000
WNW	0.0006	0.0016	0.0000	0.0000	0.0000	0.0000
NW	0.0030	0.0042	0.0000	0.0000	0.0000	0.0000
NNW	0.0013	0.0021	0.0000	0.0000	0.0000	0.0000